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BIOCHEMISTRY—*Some modern aspects of enzyme catalysis.*[1] A. K. BALLS, Bureau of Chemistry and Soils.

It may appear to you at first sight as an understatement, but the fact is that all of us live, move and have our being by the grace of enzymes. This is not a new idea. People recognized the existence of a mysterious directive force in living tissues long before they had the technical jargon with which to talk about it. The attention of the old timers was naturally directed to fermentation and digestion. They talked of a principle that was called "fermentatio," from which comes our word ferment. When they found that fermentatio occurred in yeast it gave us our word enzyme. Digestion also was directed by a mysterious force that transformed food into living tissue, just as an alchemist transformed base metals into gold. No less a person than Paracelsus von Hohenheim said so in the early fifteen hundreds. There were then no adequate words to express a scientific idea, but Paracelsus said in part

> The alchemist separates the bad from the good, and changes the good into a tincture which tinges the body with life. . . . This alchemist dwells in the stomach . . . and as soon as the food comes into the stomach the alchemist is at once there and proceeds to digest it, rejecting that which is not healthful to the body into a special place, in order that the good may go where it belongs. And remember that each animal has its own peculiar food and its own special alchemist for the digestion thereof. The alchemist of the ostrich has the faculty of digesting iron. (*The author makes no mention of the goat.*) The hog eats dung, which is the bad part of food that has been cast off by the alchemist of man and other animals, and the alchemist of the hog can separate food from dung which the alchemist of man was unable to extract. For this reason pig's dung is not eaten by any animal.

Besides the fermentation and digestion which intrigued our forefathers, another type of enzyme action is now recognized, namely tissue oxidation. The data on these three reactions constitute what today may be called enzyme chemistry. It is a large subject for a

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small talk, and is best handled by the well-known expedient of starting in the middle and going backwards and forwards at one and the same time.

Technically speaking the enzymes are catalysts, which means that they may accelerate a reaction but cannot initiate one. All the reactions in a living cell would go on without enzymes, but they would proceed so slowly that the cell would die waiting for food to be digested or oxygen to become available. And once dead, the cell would take a long time to decay and disappear if there were no enzymes in the dead tissue to speed up its disintegration. Dead cells produce no enzymes, but enzymes formed during life disintegrate the dead cells.

Nearly all of the reactions of biochemistry fall naturally into two groups, the reactions of hydrolysis and the reactions of oxidation, and each kind of reaction is accelerated by its own particular ferments. Hydrolysis is essentially a process of breaking down, oxidation a process of energy liberation that permits of building up. In life the two processes nearly balance each other, with the oxidation processes having somewhat the edge on the others. After death, oxidation ceases, and hydrolysis holds sway alone. Decay is a hydrolysis.

Because our enzymes start nothing, but only keep things moving quickly, you might suppose that they exert no directive effect on life processes. This however would be a mistake. The complicated materials of biochemistry can usually react in more than one way. A particular enzyme will catalyse only one of these possible reactions.

TABLE 1.—EFFECT ON THE END-PRODUCTS CAUSED BY CATALYSING ONE OF A PAIR OF REACTIONS

Reaction	Normal Velocity	Catalysed Velocity
A→B	1	100
A→C	10	10
$\frac{B}{C}$ at end	$\frac{1}{10}$	$\frac{10}{1}$

The diagram in Table 1 shows what would happen if a relatively unimportant reaction (A→B) were accelerated a hundredfold, while a reaction originally more important (A→C) went on at the same rate as before. Judging by the end-products formed, the importance of the two reactions would be reversed. Instead of the second reaction representing the main course of the process, the first would do so during the catalysis.

This is an example of enzymic specificity, by which is meant that an enzyme accelerates a particular type of reaction on a special group of closely related substances called its substrates. A lipase

does not catalyse protein decomposition, nor does a proteinase hydrolyse fats or carbohydrates. There seems to be a singularly definite division of labor between our ferments, hence the enzymes are best called by the substrates they act on.

You have doubtless heard that we know nothing about the nature of enzymes. This used to be true, if you go back far enough. Only a few years ago, in 1900, people thought of them as alive. As late as 1920 it was thought by many that enzymes belonged to a special class of matter that had never been chemically recognized. In a sense they do—they are proteins. (I say this with all due apology to the protein chemists, but I am unsure how much apology is owing.)

We know that many enzymes are proteins because in recent years crystalline proteins have been isolated that are these enzymes. In Figure 1 are shown photographs of crystalline proteinases from the animal digestive tract prepared in my laboratory by the methods of the discoverers, Northrop for pepsin (a) and Kunitz and Northrop for chymotrypsin (b). Plants as well as animals carry protein-digesting enzymes. Dr. Lineweaver, in our laboratory, has crystallized papain (Figure 1, c), the proteolytic enzyme of the papaya plant, the enzyme that is now used by the ton in making meat tenderizers. We would probably all be surprised to know the exact number of years of beef-life that is taken out of the steaks of this country by means of papain.

The crystallization of these proteins is usually not difficult, provided one first obtains them in the pure state. This sometimes requires considerable ingenuity. For example, Dr. Martin of our laboratory found that tobacco virus could be freed of other protein by treatment with trypsin. The trypsin digests the other proteins but not the virus. This scheme has greatly facilitated the preparation of the crystalline virus discovered by Stanley.

But though the enzymes are protein, it is quite evident that the catalytic properties must be due to some particular grouping or configuration in the molecule. As a matter of fact many enzymes behave as though this group was attached to the protein molecule in the form of a more or less separable entity, just as hemin and globin together constitute hemoglobin. Hemoglobin has been split into its two constituents—the protein and the iron-containing hemin—and then put together again. The same thing has been done in Warburg's laboratory with an oxidative enzyme called the yellow ferment. According to Willstatter's famous theory (made up long before anyone had proof of all this) an enzyme contains an active or functional

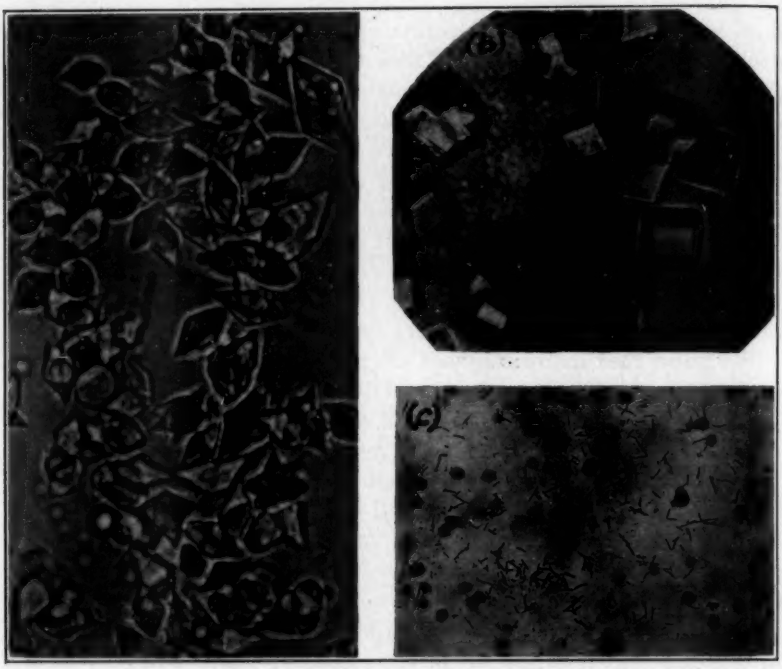

Fig. 1.—Crystals of (a) pepsin, (b) chymotrypsin, and (c) papain.

group attached to a much larger colloidal particle which present day experience seems to indicate is a protein. The nature of these functional groups has been determined in several cases.

The pyridine nucleotides appearing in Table 2 are related to nicotinic acid amide, the anti-pellagra vitamin; so that in perhaps 4 cases the active groups of the enzymes are related to the vitamins, and the idea has already been put forth that the function of such vitamins is to enable the body to synthesize the corresponding enzymes.

From the last table it is evident that two proteins form two different enzymes by combining with the same active group. As Warburg has pointed out, when an active group like cozymase is present in a system it acts as though the addition of one or another specific protein will catalyse one or another separate step in the process of fermentation. On this basis all dehydrogenases may be combinations of cozymase with various proteins.

The active group evidently performs the chemical reactions necessary to the catalysis, but the colloidal carrier is not without influence

TABLE 2.—COMPOSITION OF SOME ENZYMES

Enzyme	Reaction	Protein	Active Group
"Yellow Ferment"	Oxidizes the phosphopyridin nucleotides.	"Flavin Protein"	Phospho-flavine (Phosphorylated Vitamin B_2)
Hexose monophosphate dehydrogenase	Hexose monophosphate→ phospho-hexonic acid	"A" Protein	Triphosphopyridine nucleotide
Acetaldehyde dehydrogenase (alcohol oxidase)	Alcohol→Acetaldehyde	"B" Protein	Diphosphopyridine nucleotide (cozymase)
Pancreas lipase	Hydrolysis of fats and esters	"Lipase Protein"	Related to Ascorbic acid
Liver esterase	Hydrolysis of simple esters only	"Esterase"	
Carboxylase	$CH_3CO \cdot COOH \rightarrow CH_3CHO + CO_2$		Mg+diphospho-aneurin (Phosphorylated Vitamin B_1)

on the behavior of the active group. Differences in size or shape or electrical charge between two carriers can certainly affect the speed with which the active group functions. This has been shown in the case of the sugar-splitting ferments, and also with the enzyme catalase. A whole series of "catalases" has been prepared by Stern. They are combinations of the same hemin, the active group, with different proteins. Thus in a sense hemoglobin is one variety of catalase and in fact any compound containing iron seems to be able to decompose H_2O_2 to some extent (Table 3). Each of these combinations has a different activity. Incidentally, the compound of hemin with the natural "catalase protein" is many thousand times the most efficient.

TABLE 3.—CATALASE EFFECT OF IRON

Iron in the form of:	Relative efficiency:
ions (Fe'' or Fe''')	10^{-5}
hemin	10^{-2}
hemin-globin	10^{-1}
hemin-catalase protein	10^{+6}

Thus an enzyme is like a man; it works with its hands, but its personality, so to speak, depends on its whole body.

Thus we know that the carrier particle affects the work of the ferment, but we probably know more about the mode of action of the active group itself. The active group combines with a particular characteristic group in the substrate. There are peptidases that anchor themselves to the free amino group of a peptide, and separate the amino acid to which that group belongs from the rest of the peptide. Similarly, another peptidase combines with the free carboxyl

group in a peptide, and splits off the amino acid that bears it. If the amino group in the one case or the carboxyl group in the other is altered in any way, the whole peptide is protected against the action of the enzyme in question.

The actual reaction of the active group has been worked out by Warburg for one case, that of the transport of hydrogen by the diphosphopyridine nucleotide known as cozymase.

Thus the enzyme is able to attack only those substances having the necessary characteristic group. This limits its field of action to a comparatively small list. There is in this a beginning for understanding the phenomenon of enzymic specificity. But the presence of the necessary anchoring group in the substrate is not the only condition necessary for enzyme action.

Dr. Matlack and Mr. Tucker in my laboratory have observed with the fat-splitting ferment of the pancreas a phenomenon that might well be called pseudo-specificity. The specificity of this lipase for certain fats depends on the temperature. Apparently the molecules of some fats are too inert to combine with the enzyme under all conditions, but do combine at relatively high temperatures. These fats are therefore digested only at high temperatures. Other fats are digested at all temperatures and some are split rapidly below zero even when frozen. It depends on the size and type of the fatty acid. This observation bears on how well natural fats or fat meat will keep in cold storage. The fat in the meat varies with the kind of animal and with that animal's diet. So one kind of meat may keep better than another, and its keeping qualities may depend on what the animal was fed during its life.

The fats are not the only things that digest in cold storage, although they seem to go the fastest. Proteins are also affected, but it is not so easy to show this. A protein is such a large molecule that it is difficult to tell whether it has been hydrolyzed or not until the breakdown becomes very profound. Such a profound breakdown does not occur in the cold, but slighter changes do take place. We have shown that in this way: Most of the protein-digesting enzymes are able to clot milk. Mr. Hoover was able to show in the case of papain that there is a very curious relationship between the time required to clot the milk, the temperature and the amount of enzyme. The same type of information is also known for other protein-splitting enzymes, among them pepsin, although the relationships are different. If a little pepsin is added to milk—for example, enough to clot it in exactly an hour at 30°—and the milk is kept for a long time in the cold, apparently

nothing happens. But when the milk is warmed up it clots immediately instead of requiring an hour. Evidently part of our enzyme reaction has been going on in the cold.

By now I suppose I have given you the picture of a live cell as a very busy place, where all the wheels are turning as fast as possible, the ferments supplying the grease. This is largely but not wholly true. An enzyme cannot start a reaction, although as you saw, it has

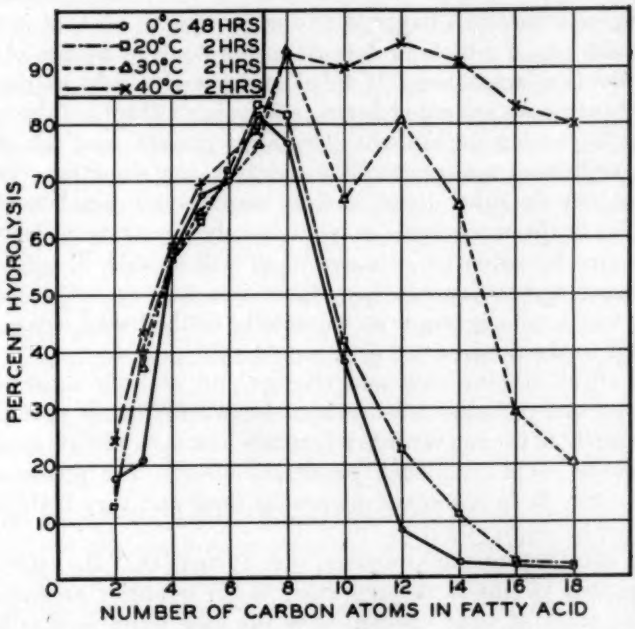

Fig. 2.—Effect of temperature on the digestion of several triglycerides, showing that the comparative rate of hydrolysis at 0° depends on the carbon chain of the acid in a saturated triglyceride.

a great effect on the result. But there are substances which can start and stop the enzymes. For want of better words, they are called activators and inhibitors. We know only a little about them. For example, in the papaya plant the enzyme which Dr. Lineweaver crystallized occurs along with a substance like glutathione. The presence of such a substance increases the enzyme action enormously. Other substances are known that have the same effect, cyanide for one and cysteine for another. This is not altogether a matter of purely academic interest. Dr. Hale has lately discovered that an enzyme

very similar to papain existed in traces in wheat kernels. A little of it gets into even the finest white flour, and its effect there is to soften the dough. It is all very well to have your dough softened, provided that the softening does not go very far. If it goes too far, the bread is heavy and poor. The importance of this observation rests on the fact that Dr. Hale's enzyme is like papain in being activated by glutathione, cysteine and other reducing agents, and conversely in being inhibited by oxidizing agents. So if the wheat proteinase is inactive, as sometimes happens during a drought, all that is needed is the addition of a little proteinase to the flour, or a little of one of the activating substances. It takes surprisingly little to get a big effect, because we are not changing the main reactants of the system, but are increasing the amount of catalyst present, and the effect of a few additional milligrams of a catalyst can sometimes be very striking. On the other hand, if flour contains too much proteinase (and this is the more usual case) it is only necessary to inactivate the enzyme by oxidation. Storage in air will do this, likewise traces of chlorine or bromate. In fact, there is a long series of oxidizing agents which usually improve the quality of the bread when a trace is added to the flour.

The effect of bleaching and storage and of such substances as bromates and persulphates has been known for many years, but it was a puzzle to cereal chemists to explain how such minute quantities of reagents could have such ponderous effects. The reason is that there is very little proteinase present in flour and very little reagent is needed to inactivate it.

As a corollary to the foregoing, it is evident that the effect of an enzyme may be out of all proportion to the quantity present if you give the reaction time enough, as is the case when food is kept in storage. An egg, for instance, takes up oxygen and gives off carbon dioxide all the time it is going down hill. However, if you prevent oxygen from entering and carbon dioxide from escaping you hinder the reaction. The catalyst has no option in such circumstances. This is the principle behind Dr. Swenson's process of pumping the air out of eggs meant for storage and coating them with a layer of heavy oil that seals up the shell pores. I know this sounds theoretical but I have also eaten the eggs. If on the other hand you wish to dry the whites of eggs you will find that you cannot properly dry the thick jelly from a fresh egg. If it stands long enough, the jelly-like white gets thin and then can be dried very nicely. But Dr. Swenson has found that the long period of standing is unnecessary if a little pro-

tein-digesting enzyme is added to the fresh egg white. In a few hours it is thin.

These are some of the important things we now know about enzymes, and some of the curious ways in which this knowledge may be twisted to become of industrial value. In general there are two kinds of practical questions—those of stopping enzyme action in dead material you wish to keep whole, and those of maintaining enzyme action on living material you wish to keep alive. The former case concerns the Food Research Division, the latter concerns us all.

I hope ladies and gentlemen that I have not disillusioned you. The living things of 1898 became the unknown catalysts of 1918 and are proteins in 1938. They are still the most mysterious of all substances; the least known; the most powerful; the closest approach to Maxwell's demon that nature seems able to make. We know very little about them yet we have made amazing progress in our knowledge. If you think any of my statements sound fantastic, let me take refuge in the words of the rhetorician Isocrates, written in the fourth century before Christ, "Can anything be supported by stronger evidence than by the oracle of the gods, the assent of many Greeks and the harmony of ancient legend with the deeds of today."

PALEONTOLOGY.—Setigerella *and* Worthenella, *two new subgenera of* Productus.[1]

GEORGE H. GIRTY, U. S. Geological Survey.

At the time of this writing probably more than 50 names have been proposed for different groups of the old genus *Productus*. Dunbar and Condra list 42 and a number have since come into the literature. Some of these names are partial or complete synonyms; on the other hand, there are a number of Productoid types that have been overlooked but deserve distinction quite as much as some of those that have been named. These genera, if we may give them that rank, possess different degrees of distinction; they have been differently interpreted and differently classified by different authors, certain ones being considered genera by some, subgenera by others, and of no consequence at all by still others.

I am not wholly sympathetic with the movement which has led to the division of *Productus* into so many genera, but for the time being I would like to cooperate with it in two ways, (1) by using as subgenera under *Productus* the names already proposed where the

[1] Published by permission of the Director of the Geological Survey. Received Aug. 6, 1938.

application of the name seems not open to question, and (2) by naming other subgenera that seem to me to be equally worthy of recognition with those so accepted. If experience proves that the use of these names is not practicable or helpful, it would seem wise to abandon them. As they differ in systematic value, some are more likely to be retained than others. A decision cannot be reached out of hand but only after a period of trial.

Setigerella subgen. nov.

The type species of this subgenus is *Productus setiger* Hall.

The holotype of *Productus setiger* has been figured by both Hall and Stuart Weller, and I also have had the privilege of examining it. The description and figures given by these authors, though adequate in most respects, omit one feature that in my judgment has much significance. The type specimen, which retains both valves in articulation, is flattened on a slab of shaly limestone in such a way as to expose the dorsal valve but conceal all of the ventral valve except the umbonal portion and two tufts of slender spines projecting obliquely outward from the auriculations. The dorsal valve appears to be flat or nearly so over most of its surface, but it is bent upward abruptly about its margin to form a narrow, well defined trail. So far, the facts are of record. The character that I have not seen mentioned is that the marginal part of the dorsal valve is doubled back on itself to form a sort of trough or gutter. The structure recalls in a measure a similar one in *P. wortheni* and *P. marginicinctus*, but it is really essentially different for in those species the marginal part has the form of a ridge or outward-facing arch. A few other characters of the dorsal valve will bear repetition in this place, namely the fine sharp costae which are crossed by obscure concentric plications and the spines which are somewhat sparsely developed over most of the surface but more generously on the auriculations. On this head Weller says "Scattered spine bases occur about as on the opposite valve, [that is, scattered rather generally] increasing in numbers upon the cardinal auriculations."

S. setigera appears to be a rather rare species in the typical region. Weller, for instance, figured only two specimens, the holotype (which shows mainly the dorsal valve) and a somewhat crushed ventral valve from Hamilton, Illinois. I have a small number of specimens (15 or so) from the Keokuk limestone at Keokuk and Warsaw, and as some of these, both dorsal and ventral valves, have a reflexed rim like the type specimen I believe this to be a constant character of the species. It is, of course, a character that would not be shown by immature specimens because it had not yet been developed nor shown by mature ones that were imperfect at the margin. These causes are adequate to explain why some of my specimens from the Keokuk localities do not show the marginal channel.

Setigerella setigera, or a species extremely similar to it, occurs in the Boone limestone of southwestern Missouri and northeastern Oklahoma; only in this area these shells are abundant and many are somewhat larger than any that I have seen from the Keokuk limestone. Some of the specimens examined are testiferous and very well preserved; others occur as molds in fine-grained chert. Molds in any fine-grained material commonly show certain characters more clearly than specimens that retain the shell, for testiferous specimens are usually more or less exfoliated. I propose to

redescribe *S. setigera* from the abundant and well preserved material at my command as a record of the characters shown by the species in an area somewhat removed from the one in which it was first recognized.

Productus (Setigerella) setiger Hall Figs. 1–7

Ventral valve.—Many of the specimens under consideration are somewhat larger than the holotype (and many also smaller), the largest having a width of about 50 mm as against 45 mm for the type. The length measured from the umbo is about equal to the width (slightly more in some specimens and slightly less in others), but if the length is measured from the hinge line the width is much the greater. From these measurements it would be rightly inferred that the umbonal parts project far beyond the hinge when the shell rests upon its aperture. The shape, consequently, is very irregular, the margin having a transversely subquadrate outline interrupted by the backward projection of the umbonal parts which conceal much of the hinge line. The convexity is high, the vault widening rapidly to the anterior margin and having an elongate triangular shape, more rarely quadrate. The sides of the vault descend steeply to the auriculations which are much less oblique and which if not broken are rather large. The cardinal angles are essentially quadrate. Apparently they are in some specimens slightly extended and in others slightly rounded, possibly by accident. A median sinus is a constant feature, though it may be so faint as to be hardly appreciable. More commonly it is rather strong and causes a perceptible emargination in the anterior outline.

The sculpture comprises radial costae, concentric corrugations, incremental lines, and spines. All these features are more or less interrelated in their development and differ in different specimens and on different parts of the same specimen. In the large, the sculpture appears very even and regular, but examined more closely it is seen to abound in small irregularities. The round costae are slender and rather uncommonly sharp in their definition, rising abruptly from rounded striae of about the same width or slightly less. Six or 7 costae are covered by a span of 5 mm, though they are apparently finer on some shells than on others. The spines are small, very numerous and, except for a tuft on the auriculations, rather regularly distributed. They are so small that they affect the costae very little, and as practically all specimens are denuded of them, they are hardly noticeable without a lens. Here and there a costa may bifurcate where a spine makes its appearance, or it may become somewhat elevated behind the spine and depressed in front of it. This last performance is more common over the visceral disc than farther forward, but it is rarely pronounced even there. On the lateral parts where the spines are especially numerous the costae are apt to become irregular and sometimes discontinuous; this heightens the appearance of the spine as arising from an elongated spine base. As already mentioned, a tuft of slender oblique spines is developed on each of the auriculations.

The spines, as in other species of *Productus*, are tubes which communicate with the visceral cavity by means of a small opening, many of which as growth proceeded became closed by deposits of shelly material. On internal molds of *S. setigera* the posterior part of mature specimens rarely shows any evidence of the spines that were dispersed over the exterior, but such evidence is generally distinct over the anterior half or more. On some specimens, presumably old ones, a deposit of shell was apparently laid around the opening of the spines, forming a ring; the internal mold is then pitted with

round holes considerably larger than the spines of which they are the evidence. The concentric corrugations are as a rule strong, regular, and of good size on the sides of the vault, but they rapidly lose strength and regularity in passing across it. Specimens vary greatly in the character of this intermediate region. In some the corrugations are fine, regular, numerous, and faint; in others they are few, strong, and irregular; most, however, show intermediate conditions. It is not practicable to distinguish between mere corrugations and varices of growth; some of the stronger and more persistent corrugations may be varices. The corrugations are not confined to what might be called the visceral disc, though they are strongest in that region. On some specimens they are continued, though with diminished strength, far down the anterior slope. The corrugations become more or less obsolete on the auricles which are thickly covered with small spines. On the sides of the vault where the corrugations are strong, they tend to interrupt the costae, or cause them to be irregular and they also, to a considerable extent, control the distribution of the spines which generally rise from their crests. Well preserved surfaces show incremental lines which, if especially distinct, consist of regular concentric lirae which give the relatively coarse radial costae a crenulated appearance.

Dorsal valve.—This valve is seen to best advantage in the form of external molds in chert for external molds in limestone are more or less covered with shelly material which obscures the surface characters. Dorsal valves in their proper form as concave objects have not come under my observation. As an external mold this valve is of low convexity for the visceral disc is but gently arched and the trail is narrow. The visceral cavity therefore was capacious. The visceral disc and the trail are directed at nearly right angles and are connected by a short strong turn. As the trail approaches the hinge at the side it rather abruptly bends upward, forming a round groove which at the margin is broad and deep, but almost disappears before reaching the beak. The auriculation defined in this way is large, rounded, and very oblique.

The surface characters of this valve are in general like those of the ventral valve. Concentric corrugations are regular, and strong on the sides of the vault but diminish both toward the hinge and away from it. Those near the beak may extend to the hinge; the more lateral ones fall far short of it. Over the intermediate part of the vault the corrugations are much fainter and more irregular varying from specimen to specimen. Small spines are scattered rather liberally over the surface and are especially numerous on the auriculations. It has not been possible to observe this feature on two valves of the same individual, but though actually numerous, the spines

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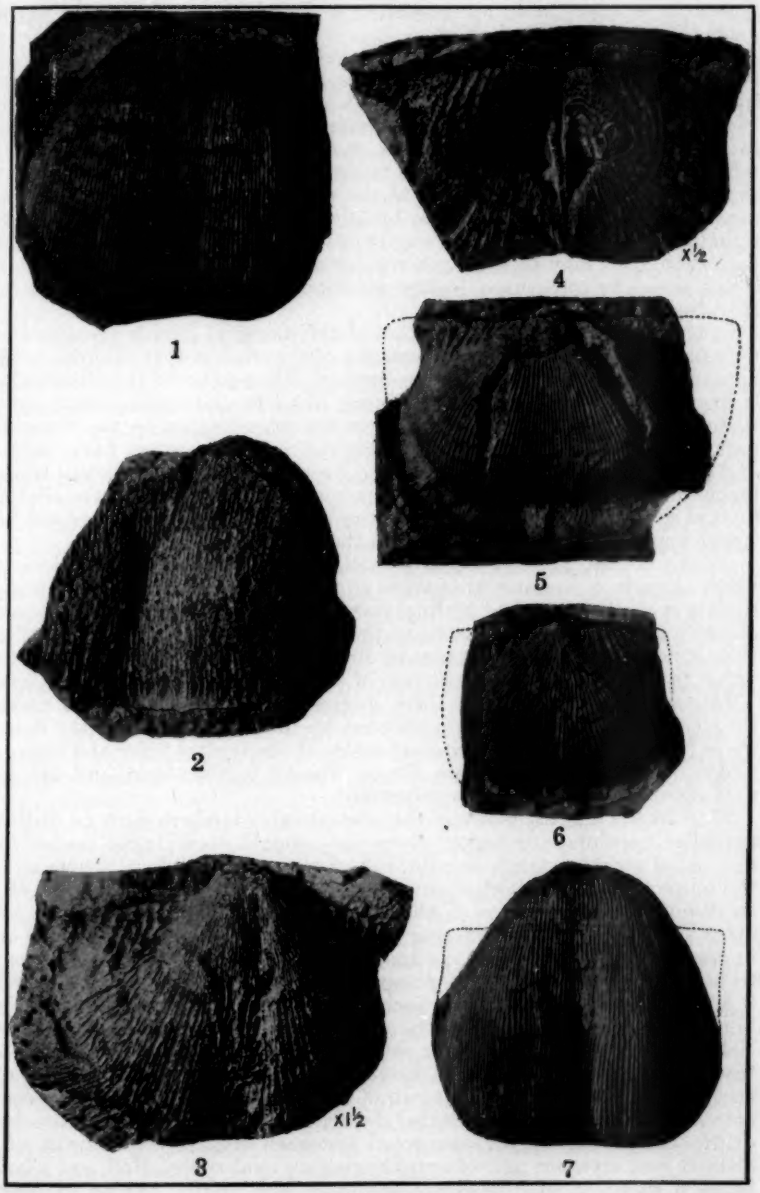
Figs. 1–7.—The localities for originals of these figures are as follows: Fig. 1, residual chert (station 7971), Webb City, Mo.; Figs. 2 to 6, residual chert (station 1310-B), Seneca, Mo.; Fig. 7, near the top of the Boone, on Grand River in the Wyandotte quadrangle, Arkansas (station 4021). All figures except 7 represent molds in chert, fig. 7 represents a testiferous specimen. Fig. 1 represents a large ventral valve which through breakage or non-development lacks the distinctive marginal rim. Fig. 2 represents a crushed ventral valve with the marginal feature as commonly seen. In some ventral valves the marginal rim is extended and upturned. This specimen also shows the pits made by annular deposits around the apertures leading into the spines. Fig. 3 shows the peculiar musculature apparently ending below in two rounded independent scars. Fig. 4 shows the musculature of the dorsal valve. Fig. 5 represents a dorsal valve with a highly developed marginal rim. Fig. 6 represents a smaller specimen also with conspicuous marginal features. Fig. 7 which represents a testiferous specimen can be compared with fig. 1 which represents an internal mold. This specimen also lacks the marginal trough though numerous testiferous specimens retain it.



Figs. 1–7.—*Productus* (*Setigerella*) *setiger* Hall. For description see opposite page.

appear to be appreciably less numerous and perhaps smaller on the dorsal valve than on the ventral valve.

Both valves at maturity exhibit a peculiar feature not as yet described but already referred to as present in the holotype and in other specimens from the Keokuk limestone at Keokuk and Nauvoo. It is indicated by Weller's illustration of the holotype, though not clearly, nor is it mentioned in his description. At maturity the marginal parts of both valves are reflexed to form a very pronounced trough or collar so that a section down the middle would be hook-shaped at the anterior end. This structure varies considerably in detail; it may be broad or narrow, it may be angular or rounded in section, it may be directed outward from the aperture or strongly backward, or it may be even and regular or rather strongly undulating. It seems generally to be more highly developed on the dorsal valve than on the ventral valve.

In the ventral valve the deflection of the marginal part is accompanied by a fairly strong and abrupt thickening of the shell so that internal molds appear also to be constricted at the aperture. The surface of the constriction is uneven, some of the costae becoming obsolete and others maintaining themselves in added size without however extending on to the recurved part. On the outer surface of the collar the radial costae are finer, fainter and more irregular than elsewhere, and over a certain part adjacent to the hinge line they die out completely, that part being marked by crenulating lines of growth such as cover the entire surface. As one would expect, no spines apparently are developed upon the collar.

On the dorsal valve the collar essentially duplicates that of the ventral valve though it commonly appears to be more extensive. The external surface is similarly marked by fine, rather faint radial costae which become obsolete over the parts adjacent to the hinge line so that even the collar, though not defined by any change in direction as it is across the front of the valve, is distinguished from the rest of the shell by a change in sculpture.

Internal structures.—Where these specimens occur in the form of molds, the ventral valve is mostly represented by internal molds and the dorsal valve by external molds for external molds of the ventral valve and internal molds of the dorsal valve are almost always fragmentary, and apt for that reason to be neglected in collecting.

Most of the internal molds of the ventral valve in chert show no distinct muscular imprints; the region where they should occur being marked by fine radial striation much like the rest of the surface. Where shown at all the musculature is somewhat out of the ordinary. It can be observed on a small number of specimens of which the one figured is representative. The other specimens, though differing somewhat in detail agree with that one in essentials. In the figured specimen (Fig. 3) the muscular tract appears to be narrow and elongate. Beginning some distance in front of the beak, it divides posteriorly into two branches and at the anterior end it terminates in two rather large oval scars. The part immediately above the scars especially is covered by an irregular reticulation of thin ridges. The muscular tract as here seen was the seat of the adductor muscles. *Productus* is generally described as having but a single pair of adductor muscles and they are characterized by having a complicated dendritic pattern. Anterior to the dendritic scars, however, an occasional specimen retains the imprint of a distinct and separate pair of scars having an oval shape. Hall and Clarke figure a specimen of "*Productus semireticulatus*" which has an accessory pair of adductor scars (Fig. 17, Pl. 17A). In general plan the imprints of the adductor muscles in that specimen and in this are closely comparable.

Broadly speaking, only exceptional specimens show the musculature of the ventral valve at all clearly, and the scars most commonly preserved are two large fan-shaped imprints made by the diductors, which may have definite outlines but are often distinguishable more by their radial striation. The diductors in the figured specimen of *S. setigera* are also distinguished in that way, but only as a variant from the rest of the surface which is also striated. The scars are sharply defined across their posterior end, partly by being just a little though abruptly depressed, and partly by being abruptly though just a little more coarsely striated. In both respects the scars seem to merge anteriorly with the rest of the surface. Such is their character on the internal mold; on the interior of the valve these features would be elevated. The diductor scars would be slightly though abruptly elevated across their posterior ends and the diductor tract as a whole would stand up still higher.

Of internal molds of the dorsal valve I have, in contrast, only a very few specimens, and here too the musculature appears to show a certain individuality. In *Productus* generally the dorsal valve bears a median septum which divides the impressions of the adductor muscles, these scars being strongly dendritic and rarely distinguishable into anterior and posterior elements. In addition, there are the so-called brachial ridges, which are loop-shaped and extend laterally from the anterior ends of the adductor imprints. This brief summary, I should state, is abstracted from Hall and Clarke. I have two internal molds of *S. setigera* which show the musculature and show it in the same way. The median septum is strongly developed, reaching about half the length of the valve. It is thin and high in the anterior part but as it passes backward it thickens, and becomes a stout ridge which joins a similar stout ridge that borders the hinge line to form a T-shaped figure. From the center of the hinge line, as if a prolongation of the septum, projects the stout cardinal process. The adductor imprints are sharply defined, but my specimens are without evidence of the branchial ridges which, however, can safely be assumed to be potentially present. The adductor scars consist of two subovate or triangular areas which are deeply excavated at the anterior end but only slightly excavated at the sides. The anterior depression is continued forward along the septum in a groove which rapidly becomes narrower and shallower, so that with this included the muscular tract as a whole has a somewhat cordate shape. The lateral and posterior parts of the adductor impressions have the normal vermiculate structure. The oblique anterior outline is somewhat lobate and two lobes on each side of the septum are especially conspicuous. The pair that are adjacent to the septum are so well marked as to suggest that they at least are independent points of muscular attachment. Different figures published to show the interior of the dorsal valve of *Producti* differ materially; the interior of *S. setigera* agrees with some, but not with others.

Almost all authors have shown caution in using internal characters of *Productus* for generic distinction. Some have said that the internal characters show little differentiation. This is perhaps not so true as that the internal characters of a species are not constant in detail and that, in addition, internal characters are so seldom open to observation as to destroy their utility from a practical standpoint. I hesitate to place great reliance upon the constancy or the individuality of the internal characters shown by my specimens of *S. setigera*, as described above.

The shells that I have been identifying with *Productus setiger* are extremely similar to a species that Moore figured as new under the name *P. newtonensis*. In fact, I can hardly doubt that they belong to the same species

in spite of the fact that Moore does not mention some of the characters described above such as the marginal collar, and in spite of the fact that the two forms apparently came from widely separated horizons in the Boone. Moore's species is said to have been found in his Reeds Spring limestone, the horizon of which is some distance below the Short Creek oolite member, whereas my specimens came from 80 feet above the Short Creek oolite. A detailed exposition of this point seems desirable. I have a large collection from the residual cherts at Seneca, Mo., which contains *S. setigera* in abundance. The stratigraphic position of this fauna is of course conjectural. My testiferous specimens from the Joplin district were collected on mine dumps and of those specimens also the stratigraphic position is conjectural. Next, I have two good series of specimens from a whitish limestone in the Wyandotte quadrangle, Okla. One of these was made by Siebenthal and the locality is not at present known to me. The other collection was made by P. V. Roundy and myself, and not improbably came from nearly the same spot as Siebenthal's. The horizon of this collection was thought to be near the top of the Boone, but as we were uncertain whether some overlying beds did not also belong to the Boone the stratigraphic evidence of these two collections is likewise dubious. Finally, I have several collections from some of the higher chert beds of the Boone also in the Wyandotte quadrangle. One of these was made from loose blocks in a plowed field, another smaller collection of the same lithologic character and, so far as it goes, of the same faunal character, was obtained apparently in place from a locality nearby. The horizon of this collection as nearly as could be determined was about 80 feet above the Short Creek oolite member, and the fauna as just said is like the more extensive fauna from the loose blocks in the plowed field which in turn is almost identical with the fauna from the residual cherts of similar character near Seneca. The fauna from the whitish limestone near the top of the Boone is also in accord. There is, however, another angle to this matter. So far as I am aware the identity of the "Short Creek oolite" of the Wyandotte quadrangle with the typical Short Creek oolite near Joplin, has never been established though the presumption is strong that they are the same. If, however, there are two beds of oolite such precision as the evidence seems to possess vanishes, for the stratigraphic position of the Reeds Spring limestone member of Moore is determined with reference to one of them and the position of these specimens of *S. setigera* is determined with reference to the other. Even in that event, however, these specimens of *S. setigera* and the specimens of *Productus newtonensis* apparently come from widely separated horizons in the Boone.

It seems highly probable that the form here under consideration is Moore's *P. newtonensis* and both come from the same general region but from different horizons. On the other hand, I have little doubt that the form under consideration is also identical with typical *S. setigera* which occurs perhaps at nearly the same horizon but in a different region. Moore notes the resemblance of *P. newtonensis* to *S. setigera* but says that it "may be distinguished by its greater average size, its well defined mesial sinus and fold, and the character of the costae." The costae of *P. newtonensis* again are said to be the same in number per centimeter as those of *S. setigera*, but they readily distinguish *P. newtonensis* by "their more angular form, the scattered spine bases which they bear, and the presence of interfurrows broader than the costae." The specimen figured by Moore is considerably larger than most of mine and as already noted, many of my specimens from Oklahoma and Missouri are somewhat larger than my specimens from the Keokuk limestone but they are not much larger than the holotype of *S.*

setigera. On some of my specimens from the Keokuk limestone, the fold and sinus are well developed and in some of my specimens from Oklahoma and Missouri the fold and sinus are faint. The costae on my specimens from Oklahoma and Missouri are rounded, rather than angular and the striae between them are of about the same width. In this they are like many specimens from the Keokuk limestone, but the constancy if not the reality of the difference mentioned by Moore seems to me questionable. I mean that exfoliation in some specimens might readily increase the width of the grooves between the costae and *ipso facto* make the costae appear angular. In the matter of spines the distinction from *S. setigera* which Moore claims for *P. newtonensis* is not clear. He does not mention the presence of spines at all in his description of the ventral valve of that species; in the dorsal valve he says that the costae are "ornamented by the rather numerous irregularly placed spine base nodes." Weller, writing of *S. setigera*, says that spine bases are scattered rather generally over the surface of the ventral valve, at intervals of 5 to 10 mm; on the dorsal valve he notes scattered spine bases about as on the ventral valve increasing in number upon the auriculations. It is probable that Moore merely forgot to mention them, but if spines are really absent on the ventral valve of *P. newtonensis* and abundant on the ventral valve of *S. setigera*, we have a real difference. I doubt whether any such difference exists in this feature between *P. newtonensis* and *S. setigera*, and at all events we are left in doubt on that head.

For the species which I have just described at considerable length I propose the subgeneric term *Setigerella* with *S. setigera* as the type species. One of its distinguishing characters is the reflexed margin which forms a sort of trough about the anterior and lateral rims. It may be objected that this is a character of old age and that old age characters are of no value for generic classification. Both points are open to dispute. The character in question obviously was developed late in the life of the individual but that it is a character of old age rather than a character of maturity would be hard to demonstrate. The fact that it seems to be generally present in unbroken specimens of full size would suggest that it was not a post-mature character. It would also be difficult to demonstrate why an old age character is not of systematic value. If some species developed one sort of old age character, others developed another sort, and still others developed none at all, but just ceased to grow, these facts would unquestionably be significant though how they should be rated is debatable. The practical utility of a character that did not make its appearance until a fully matured stage was reached and that was liable to be lost by marginal breakage is, however, open to challenge, but *S. setigera* can be, and in fact has always been identified as a species on other characters than the one under consideration, and the identification of specimens as belonging to *Setigerella* need not wait upon observation of the marginal trough though according to my experience that structure is present in the majority of specimens. *S. setigera* has other claims to subgeneric rank, one being the abundance of spines on the dorsal valve, a decidedly primitive character; still another perhaps can be found in the muscular imprints, which appear to have some individual features, though the value of this character needs to be further tested as to degree and constancy. Another consideration is that the species does not adjust itself well to other named groups of *Producti*. It is not in accord with the semireticulate *Producti* by reason of its irregular and faint concentric corrugations, which are more or less obsolete except near the hinge line and which are not restricted to a well-defined visceral region but on some specimens continue to be developed on the anterior slope though

rarely with the same strength. The *semireticulati* characteristically have rather coarse radial costae instead of fine ones, a few large spines instead of innumerable small ones, and a spineless or almost spineless dorsal valve. In fact, *Setigerella* is in some respects intermediate between the *semireticulati* and the *ovatus* group (*Linoproductus*). It has the fine lineation of that group and corrugations that are strong near the hinge and vague or obsolete over the vault. But it differs in the geniculate shape of the dorsal valve (*Linoproductus*, however, is not constant in that character), in the very large visceral cavity, and in the great number and small size of the spines, which are distributed over both valves, whereas the tendency in *Linoproductus* is to have a small number of large spines on the ventral valve but no spines at all on the dorsal valve, at least in the more representative species.

There is a possibility that *Setigerella* may conflict with Muir-Wood's genus *Sinuatella*, though this would seem unlikely from her generic description. Licharew[2] remarks that the trail of *Productus* may even be concave and instances *Sinuatella* under which genus (he classifies it, however, as a subgenus) he describes a new species *Productus* (*Sinuatella*) *subsinuatus*. His description and his figures (which are not very distinct and represent only imperfect specimens) seem to show a species that closely resembles *Setigerella* in configuration. The genotype of *Sinuatella* is *Productus sinuatus* de Koninck. Unfortunately the plate (plate 56) on which that species is figured in de Koninck's work is missing from the copy in the Survey Library. Davidson, however, figures a very perfect specimen which has remarkably large and reflexed auriculations. His specimen differs from *Setigerella* in that the feature which they appear to have in common, has just the opposite distribution in each. In *Setigerella* the shell is most extended and recurved in front, the curvature and probably the extension decreasing on the lateral slopes as the auriculations are approached. In *P. sinuatus* it is the auriculations alone that are expanded and upturned; from halfway down the sides the configuration is like that of any other species of *Productus*. In fact, the contrast might be still further enlarged upon for Davidson's figure shows a flattened area extending across the posterior margin of the ventral valve which connects the two large auriculations and from which the vault, divided by a deep sinus, rises rather abruptly. Commenting on the original specimens figured by de Koninck, Davidson says that they were imperfect and that none of them "retained the peculiarly extended and reflexed ears which I have drawn with great care from some very perfect specimens, etc." Muir-Wood does not mention this peculiarity of configuration as characteristic of *S. sinuatus* nor is it shown by her figures. The main distinctive characters of *Sinuatella* (which would otherwise apparently be one of the *semireticulati*) seem to be a well-defined cardinal area in the ventral valve with the delthryium closed by a deltidium, features also mentioned by Davidson and shown by one of his figures. Licharew found a cardinal area in *Productus* (*Sinuatella*) *subsinuatus* but could not detect a deltidium. I am satisfied that *Productus* (*Setigerella*) *setiger* has no real cardinal area and deltidium like those of *Sinuatella*, so that it has neither the configuration nor the structural features of that genus.

Worthenella subgen. nov.

There are two other Mississippian species which are closely related to each other and more loosely to *S. setigera*, all three distinguished in the

[2] Licharew, B. *Permian Brachipoda of North Caucasus*. Pal. U. S. S. R. Monographe **39**: 89. 1937.

mature stages by some remarkable development at the aperture. *Productus wortheni* and *P. marginicinctus* have already been mentioned and are outstanding developments of the Productoid stock in this country. They invite and perhaps deserve subgeneric distinction more than *S. setigera* for their distinctive characters were known even from the first whereas the distinctive characters of *S. setigera* are less striking and have generally been overlooked or unrecorded. If any of our Mississippian *Producti* deserve to be separated from the rest and given a distinctive name it is these two and I propose for them the subgeneric name *Worthenella* with *Productus wortheni* Hall as the genotype. The most distinctive character of *Worthenella* is the arch or fold passing transversely across the shell at the aperture. This development is accompanied by the disintegration of the costae into innumerable fine short spine bases. The objection that might be advanced against using the reflexed rim of *Setigerella* as a generic character would seem to hold almost equally against *Worthenella*. The counter arguments also would be the same and perhaps more telling.

Insofar as I am acquainted with foreign literature, *Worthenella* is a strictly American type. In its final relapse from a costate to a spiniferous condition it recalls *avonia* but *avonia* as originally conceived lacked the marginal arch which is so striking a feature of *Worthenella*, and as redefined it lacks the transition from a costate to a spinose type of sculpture—at least that change which seemed to figure importantly in the original definition, is generally omitted from later ones.

BOTANY.—*New varieties and combinations in* Salix.[1] Carleton R. Ball, U. S. Department of Agriculture.

Willow collections are steadily accumulating as a result of the efforts of private and public collectors. This makes it possible, from time to time, to evaluate previously described species, especially those based on meager and/or juvenile specimens. It makes possible also the description of variations regarded as worthy of varietal rank. Two new varieties are described, and two new combinations made, in the present paper.

The herbariums in which the specimens examined are deposited are designated by the following abbreviations: CAS, California Academy of Sciences; CNM, Canadian National Museum; CRB, Carleton R. Ball; CUA, Catholic University of America; PC, Pomona College; SU, Stanford University; UC, University of California; UO, University of Oregon; USN, U. S. National Herbarium.

Salix alaxensis (Anders.) Cov. var. **obovalifolia,** n. var.

Folia obovalia vel obovata; petioli breves latique basi dilatata gemmam amplectante.

Shrubs, apparently low, 1-yr. and 2-yr. branchlets stout, 4-7 mm thick, mostly divaricate, densely clothed with yellowish pilose hairs, becoming gray with age; stipules lanceolate, 4–10 mm long, glandular-serrulate or -serrate, pilose; budscales 8–14 mm long, lanceolate to ovate-lanceolate, acute, densely long-pilose; leaves rather crowded on material

[1] Received July 15, 1938.

seen, stipulate on the more vigorous shoots; petioles consisting of a broadly expanded base which forms a clasping sheath for the bud, narrowed above to join the base of the blade but may develop a true narrowed petiole above the swollen base as the leaf becomes fully developed, densely pilose throughout; blades thick and firm, 3–5 cm long and 2.5–3.5 cm wide as seen, obovate to oboval, apex arounded or plicately apiculate on the larger blades but subacute on the lower smaller ones (quite possibly retuse to subcordate at base and short-acute at apex on vigorous shoots, when fully expanded), the base cuneate on developing blades but rounded on the more oboval apical blades, densely white shining pannose-tomentose beneath, thinly gray pubescent or puberulent above, especially on the sunken midrib and laterals (probably glabrate to glabrous in maturity).

Aments (only the staminate seen) sessile on 2-yr. wood, ovate-oblong, stout, 2–3 cm long, 1.5 cm wide in anthesis (the pistillate probably much longer); flower scales ovate, acute, blackish, densely long-pilose with straight white hairs; stamens 2, the long slender filaments glabrous; (pistillate aments, capsules, pedicels, styles, and stigmas probably as in the species).

In the species, *S. alaxensis*, the leaf blades are oblanceolate, elongated, cuneate at base and tapering to an acute apex. The petiole is slender and scarcely dilated at the base. *S. alaxensis* var. *obovalifolia* differs from it, therefore, in the obovate-oboval blades and the broad dilated clasping petiole, enclosing the bud. The previously recognized variety, *S. alaxensis* var. *longistylis* (Rydberg) Schneider, differs from the species, not in longer styles, but in the glabrous and often pruinose branchlets. The new variety differs from it, therefore, by all the differences mentioned in comparing it with the species and by the densely pilose branchlets as well.

The range of the species is from northern British Columbia to Alaska and Yukon. *S. alaxensis* var. *longistylis* has much the same range but probably is more common in the eastern portion of the area occupied by both. *S. alaxensis* var. *obovalifolia*, on the other hand, apparently is confined to the front range of the northern Rocky Mountains and the great interior basin to the eastward. This region is the meeting ground or separating area for the willows of northwestern America and those of northeastern America and Greenland. It also has some species peculiar to itself, as shown recently by Raup.

Much of the material heretofore brought out of this middle ground has been collected, not by professional botanists, but casually by explorers on other missions. For this reason, many of the specimens are scanty, frag mentary, and immature or incomplete and certain identification is not fully possible. Apparently, however, the new variety ranges from eastern Jasper Park in Alberta to the western shore of Hudson Bay at Cape Eskimo, and thence northward to the Mackenzie River Valley.

Specimens examined

MACKENZIE: Near Leith Point, Great Bear Lake, Edward A. Preble 290 (USN), Aug. 31, 1903. (Leaves just expanding, the largest 3.5 cm long, narrowly obovate, plicately apiculate at apex, the petiole short, stout, subclasping, pilose.

KEEWATIN: Baker Lake, on upper part of Chesterfield Inlet, Lat. 64° 30′ N., Long. 97° W., in central Keewatin, Pere A. Dutilly 444, 445 (CUA), the latter, the type, apparently had been browsed by animals some two

years before the collections were made, Aug. 8, 1936, (Both staminate and the basis of the above description.) Hudson Bay, 25 mi. south of Cape (Point) Eskimo, (in southeastern Keewatin, Lat. about 61° N.), Edward A. and Alfred E. Preble 50 (USN), Aug. 12, 1900. (A fragment with leaves just unfolding but petioles already broad and blades broadening.)

ALBERTA: Jasper Park, open mountain slope just above Brule station, Wm. Spreadborough 95809a (CNM, fragment in CRB), June 24, 1918. (The available fragment is too small and immature for certain determination but apparently belongs here.)

Salix caudata var. **bryantiana** Ball and Bracelin, n. var.

A forma typica per ramellos aetatis uni aut duorum annorum, surculos annuos, squamas gemmarum, et stipulas aut glabros aut cito glabrescentes et per petiolos minus puberulos abludens.

Salix caudata var. *bryantiana* differs from the species in having those vegetative organs glabrous or glabrate which are pubescent or pubescent-pilose in *S. caudata*. These organs include seasonal shoots, 1-year and 2-year branchlets, budscales, stipules, petioles and midveins. The seasonal shoots and petioles may be puberulent when first developed but soon become glabrate. In other characters the variety does not differ consistently from the species.

S. caudata var. *bryantiana* bears the same relation to *S. caudata* that *S. gooddingii* var. *vallicola* bears to *S. gooddingii* Ball, namely, that of a more widely-distributed and glabrous or glabrate variety in comparison with a less widely distributed and pubescent species. It is the reverse of the relationship which the pubescent variety *S. lasiandra* var. *lancifolia* bears to its glabrate species *S. lasiandra*, and which the pubescent variety *S. laevigata* var. *araquipa* (Jepson). Ball bears to its glabrate species, *S. laevigata*, so far as relative pubescence is concerned. It has the same seasons of flowering and fruiting and the same habitats, as the species, where they occur together. At the higher elevations, flowering may be somewhat later. The type specimens are C. F. Baker's No. 1151, containing both staminate and pistillate material in the herbarium of the University of California. They were collected on June 24, 1902, in Snow Valley, Ormsby County, Nevada, at an elevation of 2460–2615 meters.

It is a pleasure to name this widely distributed variety in honor of Dr. Harold C. Bryant, a graduate and former member of the faculty of the University of California, long interested in the natural history and natural resources of the State, and now Assistant Director of the National Park Service of the Federal Department of the Interior. The eleven States in which variety *S. caudata* var. *bryantiana* is known to occur contain some fourteen of the National Parks, and eventually it probably will be found in most of them.

Salix caudata var. *bryantiana* occurs along mountain streams and in meadows of the Arid Transition and Canadian Zones of the western half of the United States. It is found at elevations of 4500 to 8500 feet (1350–2550 m) or more in the southern part of its range and at correspondingly lower elevations northward. Its range extends from north-central New Mexico northward to the Black Hills of South Dakota and the mountains of

southern Alberta. Westward it extends across the Wasatch System and the ranges of the Great Basin to San Bernardino County, California, and northward in and east of the Sierra-Cascade System to southern British Columbia. Apparently it does not cross, and seldom enters, the Cascade range in Oregon and Washington. It is a plant of higher altitudes than the closely related *S. lasiandra* and therefore does not range as far south, west, or north, as that species.

Specimens examined

CALIFORNIA: *San Bernardino Co.*, 6 ft. high, Bear Valley, San Bernardino Mts. and their eastern base, elev. 6500 ft., S. B. Parish 3003, June 23, 1894 (SU). *Tulare Co.*, Soda Creek Canon near Soda Springs, Head of Kern River, elev. 6500–7500 ft., W. R. Dudley 1492a, July 17, 1897 (SU). *Placer Co.*, Tahoe National Forest, French Meadows, along Middle Fork of American River, on Sec. 16, Twp. 15 N, R. 14 E, elev. 6000 ft., L. S. Smith 1, May 22, 1931 (CRB, UC); 2 (CRB); 2626 (in part), Aug. 27, 1931, probably from same plant as No. 2 (CRB). *Nevada Co.*, Lower end of Donner Lake, A. A. Heller 6879, July 8, 1903 (PC). *Sierra Co.*, by bridge over Little Truckee River, Sierraville-Truckee Stage Road, W. R. Dudley 5524, June 12,1900 (SU). *Modoc Co.*, by Parker Creek near Modoc Natl. Forest Boundary, Roxana S. Ferris and Rena Duthie 188, June 14, 1919 (SU). *Plumas Co.*, Few shrubs, all male, east end of Bear Lake, Canadian Zone, alt. 6500 or 7000 ft., Mrs. C. M. Wilder 9331, July 10, 1912 (CRB). *Siskiyou Co.*, Jackson Lake, alt. 5900 ft., Annie M. Alexander and L. Kellogg 186, June 24, 1911 (UC, very immature).

The identifications of the Dudley collections from Sierra County, and of the Alexander-Kellogg specimen from Siskiyou County, are somewhat doubtful, owing to their juvenile condition. Possibly they may represent *S. lasiandra* Bentham.

NEVADA: *Ormsby Co.*, Snow Valley, alt. 2460–2615 m, C. F. Baker 1151, June 24, 1902, distributed as *S. arguta* var. *lasiandra* (Bentham) Anders. (PC, UC, 2 sheets, Nos. 75356 and 143186, each bearing staminate and pistillate types). *Washoe Co.*, Franktown, K. Brandegee, May, 1913 (UC).

OREGON: *Deschutes Co.*, vicinity of Redmond, Kirk Whited 444, 444a, June 3, 1921 (CRB); 506–66, April, May, Sept., 1922 (CRB); 8, May, June, 1923 (CRB); 28, June, 1923 (CRB). *Grant Co.* Along bottoms of Long Creek, near Long Creek, W. E. Lawrence 844, July 27, 1917 (CRB). Canyon City, Griffiths and Hunter 174, July 13, 1902 (CRB).

COLORADO: *Las Animas Co.*, Stonewall, Johnston and Hedgcock 493, June 19, 1917 (CRB). *Costilla Co.*, Culebra Creek bottom, San Acacia, alt. 7737 ft., E. R. Warren 70, July 1, 1912 (CRB). *Alamosa Co.*, Alamosa, south of Rio Grande River, near State St. Bridge, alt. 7536 ft., Hazel M. Schmoll 1016, 1017, June 12, 1924 (CRB). *Rio Grande Co.*, northeast of Monte Vista, alt. 7653 ft., Schmoll 1055, 1056, June 13, 1924 (CRB). Del Norte, Ellsworth Bethel, July, 1897 (CRB). *Gunnison Co.*, Abundant along creeks at Dayton, Ivar Tidestrom 1633, July 21, 1908 (CRB). Common at Gunnison, alt. 2300 m, Ivar Tidestrom 2235, 2236, June 14, 1909 (CRB). *Fremont Co.*, Canon City, T. S. Brandegee, May, 1877 (UC). Pike's Peak Region: *El Paso Co.*, Adams Crossing near Colorado City, alt. 6200 ft., I. M. Johnston 2703, (CRB, UC), 2704 (CRB) July 21, 1920, Ute Pass near

Long's Ranch, alt. 7000 ft., Johnston 2705, June 17, 1920 (UC); just east of Manitou, Johnston 2706, June, 1920 (CRB, UC). *Douglas Co.*, Lower part of Garber Creek, 8 mi. S.W. of Sedalia, Schmoll 703, June 7, 1923 (CRB). *Routt Co.*, River bank, 10–15 ft. high, Steamboat Springs, L. N. Goodding 1597, July 13 (CRB) July 20 (UC) 1903.

SOUTH DAKOTA: *Pennington Co.*, along North Rapid Creek, 1½ miles N.W. of Rochford, A. C. McIntosh 843, Aug. 24, 1926 (CRB). *Lawrence Co.*, Stream at edge of town, Deadwood, C. R. Ball 1356, Sept. 19, 1908 (CRB).

WYOMING: *Albany Co.*, Scarce, river bottoms, Little Laramie River, L. N. Goodding 4, June 14, 1901 (CRB). Sand Creek, 6–15 ft. high, along the creek, A. Nelson 6991, May 31, 1900 (CRB, UC). Chug Creek, common along the creek. A. Nelson 7346, June 30, 1900 (CRB). Centennial, A. Nelson 8834, June, 1902 (CRB). Stream near Centennial, Leon Kelso, 1021, 1037, June 20, 1930 (UC). Near Sheep Mt. in a dry, hilly locality, Leon Kelso 1004, 1011, 1012, July 5, 1930 (UC). *Sheridan Co.*, above Big Horn, alt. 4500 ft., Pammel and Stanton 207, June 26, 1897 (CRB). *Uinta Co.*, Fort Bridger, Aven Nelson 4596, June 8, 1898 (UC). Common along the creek, Evanston, Aven Nelson 7209, June 14, 1900 (CRB). In clumps 5–15 ft. high, Kemmerer, Aven Nelson 7179, June 13, 1900 (CRB).

MONTANA: *Gallatin Co.*, Bozeman, J. W. Blankinship, Oct. 13, 1900 (UC). Southeast of Fair Grounds, in swampy ground, C. R. Ball 1311, Sept. 3, 1908 (CRB). *Park Co.*, Cottonwood Creek, northwest of Wilsall, W. N. Suksdorf 924, Sept. 2, 1921 (CRB). *Powell Co.*, Mountain streams, alt. 5000 ft., Deer Lodge Valley, J. W. Blankinship 788, May 27, 1906 (UC). *Missoula Co.*, near mouth of Clearwater River, Clearwater, J. E. Kirkwood 1435, June 9, 1923 (UC).

UTAH: *Piute Co.*, Mt. Belknap, Marysvale, E. D. Ball 1763, June 22, 1912 (CRB). *Sevier Co.*, head of Salina Canon, alt. 8000 ft., M. E. Jones 5427, June 15, 1894 (UC). *Sanpete Co.*, abundant along creek near Indianola, Ivar Tidestrom 2240, June 17, 1909 (CRB). Shrub 2–3 m high, along creek at Ephraim, Wasatch Mts., alt. 1650 m., Tidestrom 1118, June 11, 1908 (CRB). *Utah Co.*, Along streams, Lehi, L. N. Goodding 1162, June 20, 1902 (CRB, UC). Common along stream at Thistle Junction, Wasatch Mts., alt. 1500 m, Ivar Tidestrom 8, Aug. 8, 1907 (CRB); Tidestrom 1095, 1096, June 8, 1908 (CRB). *Salt Lake Co.*, near Salt Lake City, Mrs. E. J. McVicker, in 1901 (UC). *Dagget Co.*, Ditch bank, elev. 6000 ft., Louis Williams 413, May 28, 1932 (CRB); Lake shore, Green Lake, elev. 7400 ft., Williams 585, June 10, 1932 (CRB). *Summit Co.*, near R. R. Station, Echo, Wasatch Mts., C. R. Ball 1825, Aug. 19, 1913 (CRB). Myer's Ranch, Uintah Mts., alt. 7500–8000 ft., South of Evanston, Wyo., Pammel and Blackwood 4106, July 26–Aug. 1, 1902 (CRB). *Morgan Co.*, Peterson Canon, Peterson, alt. 8000–10,000 ft., Pammel and Blackwood 3999, July 19, 1902 (CRB). *Cache Co.*, Ditch south of College Hill, Logan, C. R. Ball 1313, Sept. 8, 1908 (CRB). Izatt's Swamp, Greenville, Logan, C. R. Ball 1703, Sept. 27, 1910; alt. about 6000 ft., in Logan Canon, Logan, C. R. Ball 1863, Aug. 18, 1914 (CRB).

IDAHO: *Bear Lake Co.*, Creek bank, Montpelier, J. F. Macbride 17, May 15, 1910 (UC, mixed with *S. lutea*). *Fremont Co.*, Shrub 6–8 ft. high, river banks, St. Anthony, Merrill and Wilcox 820, July 4, 1901 (CRB). *Bonner Co.*, bottoms, Upper Priest River, alt. approx, 3000 ft., C. C. Epling 8608, July 1925 (CRB).

WASHINGTON: *Klickitat Co.*, Open slopes near Maryhill, J. Wm. Thompson 8184, April 15, 1932 (CRB). *Spokane Co.*, 5 or 6 miles southeast of Spangle, W. N. Suksdorf 8630, May 15, 1916 (CRB). Old bush, upper Hangman's Creek, F. A. Patty 14, May 2, 1932 (CRB, UC). *Okanogan Co.*, Head of Ross Canyon, West of Omak, C. B. Fiker 592, April 24, 1932 (CRB); Fiker 737, May 12, 1932 (UC). On Salmon Creek near weir, Fiker 612, May 5, 1932 (CRB). On bank of Okanogan River at Omak, Fiker 614, May 5, 1932 (UC); Fiker 618 and 619 (CRB), 620 and 621 (UC), all May 8, 1932.

ALBERTA, CANADA: Elbow River at Mission Bridge, Calgary, alt. 3400 ft., Malte and Watson 116725, June 28, 1925 (CRB, NMC, UC). Sand flat along Bow River, Calgary, Malte and Watson 116728, June 4, 1925 (CRB, NMC, UC).

Salix lasiolepis var. **sandbergii** (Rydberg) n. comb.

Salix sandbergii Rydberg in Bull. Torr. Bot. Club **39:** 304, 1912;—Fl. Rocky Mts. 192, 1917;—rev. ed. 192, 1922.
Salix lasiolepis, in part, of authors.
Salix lasiolepis bigelovii, in part, of authors.

Shrub 2–3 or sometimes 4 m high, sprangly or divaricately branching; branchlets softly gray-tomentose, the 2-year thinly, the 1-year and seasonal shoots usually densely so, brownish or the younger yellowish; budscales short, stout, ovate, obtusish, 4–8 or 10 mm long, colored and clothed as the branchlets.

Leaves petiolate, stipulate; stipules (on vigorous branchlets) reniform to semi-lunate or semi-cordate, 5–10 mm long, denticulate to dentate, colored and clothed as the blades; petioles rather slender, 7–15 mm long on seasonal shoots, pubescent; blades obovate or obovate-oval (on lower part of shoots) to broadly or narrowly oblanceolate or elliptical-oblanceolate or even lanceolate (on distal portions of shoots), 4–10 or more cm long, 2–4 cm wide, common sizes being 3×1.5, 4×2, 5–6×1.5–2.5, 7×2.5–3, 8×1.7–3.5, 9–10 ×3–4 cm, respectively, margins somewhat revolute, entire to irregularly and somewhat remotely glandular-crenulate-serrulate, or those of vigorous shoots sometimes closely crenate-dentate, the glands partly deciduous, the whitish midvein and slender primaries elevated on both surfaces, dull green (not shining) above, glaucous beneath, white-tomentose on both sides when unfolding, thinly pubescent to puberulent above and densely gray or silvery-gray pubescent beneath when full grown, sometimes becoming glabrate in autumn.

Aments midsize to large, precocious, sessile to very short-pedunculate, spreading; peduncles pubescent, 2–7 or 10 mm long, and bearing 3–5 or rarely 7 small leaf-like bracts which are early deciduous or the distal occasionally developing into small permanent leaves; pistillate aments 3–4.5 cm long and 1 cm wide at anthesis, becoming 4–6.5 cm long and 1.5 cm wide in fruit; capsule pedicelled, lanceolate, 4.5–5.5 mm long, brown, glabrous, the upper pedicels 1, and the lower to 2.5 mm long, glabrous, styles entire, 0.5–0.8 mm long, slender, glabrous, stigmas shorter, entire or mostly divided; staminate aments 2.5–4 cm long, 1–1.3 cm wide, sessile but with 1–4 small bracts at base; stamens 2, filaments slender, glabrous, commonly united at base; scales of both sexes obovate, rounded to subacute at apex, black, densely pilose on both surfaces with originally-straight white hairs.

Rydberg described *Salix sandbergii* in 1912 from a single immature, leaf-

less fruiting specimen collected in northern Idaho. For 20 years its identity remained unknown. On May 17, 1932, the writer, in company with Harold E. Parks and Joseph P. Tracy, two exceedingly observant botanists of northern California, discovered and collected a peculiar willow in a dry arroyo on Berry's Mt., in Humboldt County. The old fruits indicated relationship with the common arroyo willow, *S. lasiolepis* Bent., but the plant differed in many ways. In October of that year, and in April and May of 1933, a later season, Tracy collected additional good material from the same plants. The leafless flowering and fruiting spring material recalled the specimen Rydberg had described and a comparison with the type proved the identity of the plants from California and Idaho. Abundant material, collected throughout the year, proved the material to represent a well-marked variety of *S. lasiolepis*.

Salix lasiolepis var. *sandbergii* differs from the species in the more broadly oblanceolate to obovate leaves and the much denser and more permanent pubescence of all the vegetative organs, namely, branchlets, budscales, and leaves. From variety *bigelovii* (Torrey) Bebb, it differs chiefly in the denser and more permanent tomentose pubescence just mentioned.

Salix lasiolepis var. *sandbergii* is distributed at least from northern California, in both the Coast Ranges and the Sierras, across eastern Oregon and Washington and western Idaho. It has not been collected again as far north in Idaho as the type locality. The species occurs more or less sparingly throughout the same range. The variety apparently tolerates the hotter and drier situations and occupies these alone, but in more favorable situations both may occur.

It is probable that the collecting of additional complete material may disclose the variety in localities farther south and perhaps farther east also.

Specimens examined

CALIFORNIA: *Humboldt Co.* (southern), Miranda, along South Fork of Eel River, elev. 300 ft., Jos. P. Tracy 10914 (CRB, UC), 13090 (CRB), in 1933; Bridgeville, Van Duzen River, elev. 750 ft., Tracy 10126, 11 ft. tall (CRB, UC), 10130, 20–30 ft. tall (CRB, UC), both in 1932, and 10934 and 10968 (CRB), from the same plant as 10127, both in 1933; dense thickets 10–20 ft. high on Van Duzen River 2 mi. west of Bridgeville, Parks and Tracy 11005, 11006, 11007 (CRB). "Blue Slide" on Van Duzen R., elev. approx. 300 ft., Tracy 10753 (CRB) in 1932 and 10931, 10969 from same plant (CRB) in Mar.–Apr., and 13088 in Oct., 1933; Ball, Parks, and Tracy 01236 (CRB, UC), probably from same plant as Tracy 10753, 1932. *Humboldt Co.* (northern), Divaricate shrubs, 6–8 ft. high, in dry ravine on west slope of Berry's Mt., east of Redwood Creek on Trinity Highway, elev. 2500 ft., Ball, Parks, and Tracy 01323–01329, incl. (CRB, UC, USN 01323–24), May 17, 1932; Tracy 10865, 10866 (CRB, UC, USN 10865), 10867 (CRB), Oct. 8, 1932; Tracy 10959 (from same plant as B, P, and T 01324 and Tracy 10866) and 12184 (CRB, UC, USN 10959), April 2 and May 14, 1933; Tracy 10961 from same plant as Tracy 10867 (CRB), April 2, 1933. Buck Mt., shrub 15 ft. tall on lower foothills of its northern slope, elev. about 2500 ft., Jos. P. Tracy 10243, 10244 (CRB, UC), 10248 (UC), June 9, 1932. Three Cabins, shrubs 15 ft. tall, common in ravines of grassy slopes on lower western foothills of Chaparral Mt., elev. about 1500 ft., Tracy 10356, 10357 (CRB, UC), June 19, 1932. Dobbyn Creek, alt. about 500 ft., Tracy 13356 (CRB), July 9, 1934. Trinity River Valley at Willow Creek, alt. 500 ft., Tracy 9643 (UC), 12177 (CRB, UC), May 14, 1933. *Trinity Co.:*

Along stream, Weaverville, E. I. Applegate 7054 (CRB), April 14, 1932. *Del Norte Co.*, Gravel bars 5 mi. above mouth of Smith River, Tracy 9506 (CRB), May 30, 1931; Tracy 10822 (CRB, UC), Sept. 24, 1932. *Siskiyou Co.*, Siskiyou Mts., sunny south slope by well, Oak Knoll Ranger Station, Klamath River, alt. 2200 ft., Louis C. Wheeler 3363 (CRB), Dec. 13, 1934 (apical leaves of seasonal shoots still attached). Shrub to 3 m tall, in sunny seep, Greenhorn Creek, elev. 3000 ft., Wheeler 3492 (CRB), May 12, 1935. Klamath River 6 miles below Hornbrook, L. R. Abrams 9902 (CRB), Aug. 1, 1920. *Nevada Co.*, Dry arroyo above Grass Valley, Ball 2302 (CRB), Aug, 5, 1925. *Shasta Co.*, Squaw Creek, tributary of the Sacramento R. at Kennett, elev. about 500 ft., R. Ballaert (for C. J. Kraebel, For. Serv. erosion control), 1a to 1d incl. (CRB), Dec. 20, 1934; Shrubs in denuded clay soil of Kennett smelter-fume area, Redding quadrangle, east of Trinity Nat. For., C. J. Kraebel K501 (same plant from which cuttings 1a to 1d, above, were derived), K502, K503 (CRB), Sept. 23, 1933.

OREGON: *Jackson Co.*, Shrub 6–8 ft. high, by Highway 99, 5.2 mi. south of Siskiyou Pass, near Oreg.-Calif. boundary, Bertha S. and Carolyn S. Ball 2334 (CRB, UC, UO), Sept. 21, 1933. *Umpqua Watershed*, Low shrub on West Fork of Cow Creek, Cow Creek Mts., W. C. Cusick 4727a, 4728 (CRB), both depauperate, June 12, 1915. *Deschutes Co.*, Redmond, in Landes field, SE of barn, Kirk Whited (CRB), July 13, 1922; Main Ditch and Lateral C, Whited 508–68 (CRB), Sept. 3, 1922; Landes field, Whited 508–70 (CRB), Sept. 4, 1922. *Wasco Co.:* Dufur, L. R. Abrams 9517 (CRB), July 28–30, 1922.

WASHINGTON: *Klickitat Co.*, In the canyon north of Bingen, W. N. Suksdorf 10342, 10372 (CRB), April and July, 1920. Maryhill, open slopes near, J. Wm. Thompson 8183 (CRB), April 15, 1932. *Chelan Co.*, Moist creek bottom near foot of Blewett Pass, J. Wm. Thompson 6022 (CRB), April 18, 1931.

IDAHO: *Boise Co.*, Squaw (Sweet) Creek, stream banks, elev. 3500 ft., J. T. Macbride 859 (as S. Wolfii idahoensis Ball, USN), May 11, 1911. *Elmore Co.*, On banks of Canyon Creek, near Tollgate, north of Mountain Home, J. H. Christ and W. W. Ward 7028 (CRB), May 7, 1937. *Gem Co.*, In ravine in basalt cliffs, Black Canyon Diversion Dam, Emmett, Christ and Ward 6979, 6980 (CRB), May 3, 1937. *Nez Perce Co.*, Along Hatwai Creek, Sandberg, MacDougal, and Heller 71 (CRB, USN, isotype), April 28, 1892.

Salix pseudo-monticola var. **padophylla** (Rydberg) n. comb.

Salix padifolia Rydberg, in Bull. Torr. Bot. Club **28:** 272–73. 1901, not Andersson, 1858. *S. padophylla* Rydberg, nomen novum, in Bull. Torr. Bot. Club **28:** 499, 1901.

Rydberg's original description read as follows: "A shrub 1–7 m high, with light brown smooth bark. Young twigs strict, glabrous and shining, yellow, or often brown or purple: stipules ovate or rounded, glandular-dentate: leaves with petioles 5–8 mm long; blade oval or broadly elliptic, crenate, short-acute or obtusish, rounded at the base, 3–5 cm long, 1.5–2 cm wide, when young sparingly covered with silky hairs but soon glabrate, dark green above, paler beneath: pistillate aments 3–4 cm long, densely flowered, appearing usually before the leaves, borne on very short branches and subtended by 1–4 small leaves: bracts obovate, fuscous, covered on the outside

with white wool; pistils nearly sessile, glabrous; style about 1.5 mm long: stigmas 2, nearly 1 mm long, 2-cleft: capsules ovate-conic, about 6 mm long: staminate aments almost sessile, 2–3 cm long, 10–12 mm in diameter: bracts as those of the pistillate aments: stamens 2, filaments glabrous."

With some exceptions to be noted later, this is a fairly complete description of the plant Rydberg had in hand. His species, however, received scant attention then or since. The reasons were two. In the first place, he compared it only with *S. mackenziana* and *S. cordata*, two species of the Section *Cordatae*. He made no mention of the Section *Commutatae*, to which the broad and short leaves and the elongated style and stigmas clearly showed it to belong, as did also some other characters and the general habit and habitat. He did not compare it with, or even mention, *S. monticola* Bebb, the common and well known representative of the *Commutatae* in the southern Rocky Mountains where his species occurred. In the second place, the other three species of *Salix* published in the same paper were speedily shown to be either previously described or of doubtful validity and these facts tended to discredit the standing of the plant under discussion. So also did the fact that the original name was preoccupied and had to be replaced by him.

In the light of more abundant material, Rydberg's description needs some emendation. The branchlets often are not strict but more or less divaricate, as in the species or in *S. monticola* Bebb. The leaves he described were those of flowering and fruiting branches. Mature leaves on such branches, and the full-grown leaves of seasonal shoots, probably will be larger, more produced at apex, and sometimes subcordate at base. Unfortunately, no collector seems to have collected all the stages of development from the same plant. Numerous specimens of mature foliage are found in herbariums but which ones actually represent the variety and which the species cannot be known with certainty until complete specimens are available.

The description of the leaves as merely "paler beneath" rather than glaucous beneath probably was due partly to the immaturity of the material and perhaps partly to faulty drying. Too rapid drying, especially by electric driers, often destroys the glaucous character. The aments are sessile to very short-peduncled at anthesis and the peduncle elongates thereafter. The staminate aments remain subsessile. The pedicels of the capsules vary from 0.5 to 1 or 1.5 mm, especially the lower, and the capsules are not "nearly sessile," as described.

Salix pseudo-monticola var. *padophylla* differs from the species, *S. pseudo-monticola* Ball, chiefly in having the aments borne on short leafy peduncles, whereas those of the species are sessile and scarcely even bracted at base. From *S. monticola* Bebb it differs in the pedunculate aments and also in the oval-ovate leaves, resembling those of the apple, as the name indicates. The leaves of *S. monticola* are lanceolate to broadly lanceolate-oblong and acute to subacuminate.

Salix barclayi Anders., also of the Section *Commutatae*, likewise has leafy-pedunculate aments. In general, however, the peduncles are much longer and more leafy. The branchlets usually are more or less hirsute and the leaves are oblanceolate, acute at the apex, usually narrowed at base, and commonly closely glandular-crenulate on the margins. The flower scales also are longer, narrower, and acute, with longer pilose hairs. Unfortunately, however, *S. barclayi*, in its most southward extension, tends to become more glabrate, the peduncles become reduced in length, and at least the lower (distal) leaves may be broadened at the base. Immature material is difficult

to distinguish from immature specimens of the present variety of *pseudo-monticola*. Only the collection of complete specimens (flowers, fruit, and mature leaves from fruiting branchlets, and mature seasonal shoots) will enable the final solution of this problem.

The widespread and discriminating observations and collecting of Professor Edward C. Smith of the Department of Botany, Colorado Agricultural College, is producing information and material of much value in the solution of this and other problems of the Colorado willows. He recently has raised the question of the taxonomic status of the representatives of the *Commutatae* in that State and this contribution is a partial answer to the question. More complete collecting may make a complete answer possible.

It is probable that some of the mature-foliage specimens now assigned to *S. pseudo-monticola* really belong to the variety but this can be determined only after flowering, fruiting, and late foliage specimens from the same plant are available for study. The following flowering and fruiting specimens are referred to this variety.

Specimens examined

ARIZONA (east central): White Mts., south of Thomas Peak, Coville 2009 (USN), July 2, 1904.

COLORADO (western): *Gunnison Co.*, Vicinity of Mt. Carbon, elev. 2750 m., Eggleston 5671 (USN), June 11, 1910. *Hinsdale Co.* (Gunnison Watershed), Carson, elev. 11,000 ft., Baker 306 (USN), July 2, 1901. *Monterey* or *La Plata Co.*, Bob Creek, West La Plata Mts., elev. 10,000 ft., Baker, Earle, and Tracy 175 (USN, cited by Rydberg), June 28, 1898.

COLORADO (eastern): *Chaffee Co.*, Buena Vista, Eastwood 7071 (USN), June 18, 1918. *Conejos Co.*, Los Pinos, elev. 7000 ft., Baker 271 (USN, cited by Rydberg), May, 1899. *El Paso Co.*, Zanger Farm, Black Squirrell Creek, Christ 1955 (CRB), May 5, 1936; Pikes Peak Region, just east of Manitou, Johnston 2765 (CRB), June, 1920; Minnehaha, Pikes Peak, Johnston 2713 (CRB), June 2, 1920; Cog Road, Pikes Peak, Christ 168 (CRB), June 6, 1935. *Grand Co.*, Grand Lake, E. C. Smith (CRB), June 6, 1934. *Lake Co.*, Leadville, Eastwood 7143, 7144, 7154 (USN), June 19, 1819. *Larimer Co.*, Estes Park, elev. 7500 ft., E. C. Smith 446, 451 (CRB), June 11, 1934. *San Juan Co.*, Silverton, alt. 10,000 ft., Tweedy 268, 269 (USN, 268 doubtfully cited by Rydberg), July, 1895. *Teller Co.*, Divide, Christ 205, 206 (CRB), June 9, 1935; North Branch of Catamount Creek, elev. 9400 ft., E. R. Warren 9 (CRB), Sept. 2, 1926.

WYOMING: *Albany Co.*, Shrubs 3–8 ft. high, along stream, Nash's Fork, A, Nelson 7781, 7782 (CRB), July 28, 1900. Centennial, in bogs, Nelson 8823 (CRB), Aug. 7, 1902.

ZOOLOGY.—*Studies on trichinosis. X. The incidence of light infestations of dead trichinae in man.*[1] LEON JACOBS, National Institute of Health. (Communicated by W. H. WRIGHT.)

In a survey of the incidence of trichinae in man in the United States, begun at the National Institute of Health by Hall and Collins

[1] Received July 11, 1938.

(1937),[2] continued by Nolan & Bozicevich (1938),[3] and at present being carried on by the writer, two methods are used for the detection of trichina larvae in diaphragm muscle obtained at necropsy. These methods, which have been described in detail by the above-mentioned writers, are briefly, as follows:

The microscopic examination, in which one gram of muscle from around the tendinous portion of the diaphragm is pressed between two heavy glass plates in a metal press, and examined under the low power of the dissecting microscope (1.7× objective and 12.5× ocular). If live or dead trichinae are present in numbers large enough to be found by an examination of one gram, they will be revealed by this technique.

The digestion-Baermann technique, in which the major portion of the diaphragm is ground up and digested in artificial gastric juice. The residue, after sedimentation, is poured onto the screen of a Baermann funnel, and fluid from the bottom of the funnel is later drawn off and examined for trichinae. Live larvae, if present even in very small numbers, are detected by this method. Occasionally, also, calcified cysts will pass accidentally through the screen and will be found in the fluid at the bottom; the number so found, however, is not an indication of the intensity of infestation.

The two techniques supplement each other. The microscopic examination reveals live and dead cases when the infestation is of the order of at least one per gram, while the digestion-Baermann technique detects live larvae in any number. One-third of the positives are found by the microscopic examination alone, one-third by the digestion-Baermann technique alone, and one-third by both techniques. Only light infestations of dead trichinae of the order of less than one per gram can be consistently missed by both techniques. It was the purpose of the investigation recorded here to determine whether or not there exist in man infestations with dead trichinae of the order of less than one larva per gram, and if so, to what extent.

Material for this investigation was obtained from the diaphragms used in the routine studies. When large diaphragm samples were received, the major part, as usual, was digested, and one gram from around the tendinous portion was saved for the microscopic examination. An additional ten grams from regions around the tendinous portion were saved for the purpose of this second survey, and if the routine examinations showed the sample to be negative, these ten grams were examined for the presence of dead trichinae.

No attempt was made to sample the material systematically. The

[2] HALL, MAURICE C. and COLLINS, BENJAMIN J. *Studies on trichinosis. I. The incidence of trichinosis as indicated by post-mortem examinations of 300 diaphragms.* Public Health Reports 52(16): 468–490. 1937.

[3] NOLAN, M. O. and BOZICEVICH, JOHN. *Studies on trichinosis. V. The incidence of trichinosis as indicated by post-mortem examinations of 1000 diaphragms.* Public Health Reports 53(17): 652–673. 1938.

sampling was left purely to chance, and depended upon the size of the diaphragm samples received and the amount of time available for work on the study. The first ten-gram sample came from diaphragm No. 1382, and the last from diaphragm No. 1874. Thus there was a random sampling of almost 500 diaphragms. Sometimes ten-gram samples from ten or more consecutive diaphragms were examined, with the double purpose of completing the survey as promptly as possible, and of ascertaining whether any positives were being missed when long series of negatives were found by the routine examinations. In this connection, it is interesting to note that only one case was found which was not detected, but should have been detected, by the routine digestion-Baermann technique. This case represented an infestation with only one live larva per 10 grams of material. Since that time, the digestion-Baermann technique has been changed slightly. Instead of sedimentation glasses into which the fluid from the Baermann funnel was drawn, and from the bottom of which, after an hour's standing, fluid was pipetted into Syracuse dishes, small funnels from the bottom of which the sediment can be drawn, have been introduced. The use of these funnels may lessen the possibility of missing a few live trichinae.

Of 100 diaphragms previously found negative in the routine examinations, the microscopic examination of an additional ten-gram sample revealed six cases positive for trichinae. One of these cases represented a live infestation, in which one uncalcified cyst containing a live larva was found in ten grams of muscle. Each of two other positives showed one uncalcified cyst containing a degenerated larva, and each of the remaining three cases showed one partially calcified cyst containing a degenerated or dead larva. In no case was an infestation of more than one cyst found in any of the ten-gram samples. Table 1 gives detailed results of the positive findings.

TABLE 1.—FINDINGS FOR POSITIVE CASES

Diaphragm Number	Larvae per 10 grams Number	Condition of Cyst	Condition of Larva
1385	one	one pole calcified	degenerated
1437	one	uncalcified	alive
1590	one	partially calcified	degenerated
1617	one	uncalcified	degenerated
1694	one	uncalcified	degenerated
1709	one	polar calcification	dead

It appears significant to the writer that in none of the 100 examinations were positives revealed that had a greater probability than

one chance out of ten of being discovered in the routine examination of a one-gram sample. Theoretically, of course, there is a possibility of missing in the microscopic examination of a one-gram sample cases in which as many as nine cysts are present in ten grams. The writer intends to make another survey of 100 ten-gram samples from diaphragms revealing one cyst per gram in the routine microscopic examination, with the intent of determining the distribution of cysts in the muscle around the tendinous portion of the diaphragm. It is known that the larvae are more concentrated around the tendinous part of the diaphragm than elsewhere, but it seems possible, from the data presented above, that the larvae are more or less evenly distributed around the tendons.

In the regular trichinosis survey being conducted at the National Institute of Health, it has been found that approximately 17 per cent of the total number of diaphragms examined contained trichinae. According to the data presented here, probably 5 or 6 per cent of the remaining diaphragms had infestations that were missed in the routine examinations. This adds approximately four or five per cent to the total incidence figure.

ZOOLOGY.—*Notes on the "culture" of aquatic nematodes.*[1] B. G. CHITWOOD and M. B. CHITWOOD, Bureau of Plant Industry.

Most aquatic nematodes seem to require considerable aeration and it is not customary to keep such forms alive in the laboratory. To the writer's knowledge, no one has succeeded in keeping marine nematodes reproducing in the laboratory. Eventually, when their feeding habits are sufficiently understood, it seems possible that we may be able to culture aquatic nemas in test tubes. The first steps in this direction are reported in the following experiments wherein such forms have been raised in balanced aquaria.

Aquarium A.—A one quart aquarium bowl, maximum depth 3 inches, was half filled with stream water, to which a little sand, algae and a minute aquatic flowering plant were added. Culture begun October 1937. Water was added to compensate for evaporation. On April 26, 1938, male and egg-laying females of *Tylenchus filiformis* v. *abulbosus* n. var. were secured from the sediment. Gastrotrichs, rotifers and planarians also abounded in this culture. Water, pH 8.3.

Aquarium B.—A rectangular tank 28 by 12 by 10 inches was filled to a depth of 4 inches with sievings from stream, some algae and a small flowering plant (*Lemna* sp.). Kept covered to three-quarters of its length with a

[1] Received July 29, 1938.

glass plate. Culture begun October 1937. Examined at intervals and fresh tap water added to maintain water-level. *Monhystera similis* with eggs and various developmental stages (at bottom). This species apparently reproduces without males. Another species, *Anaplectus granulosus*, found on the side of aquarium, together with green slime. Other organisms found include turbellaria, gastrotrichs, hydra, a dragon fly nymph (had become almost fully grown during winter). Water, pH 7.8.

Aquarium C.—Similar to B, but equipped with small aerator, an air pump delivering stream of bubbles every few minutes. Original material from another stream (not as in A & B), flowering plant absent; diatoms, copepods and bivalves present. Culture begun October 1937. Examined at intervals and tap water added occasionally. *Monhystera vulgaris* found reproducing in moderate numbers (no males); *Prismatolaimus intermedius* also seen. This aquarium has been neutral to alkaline as evidenced by the appearance of numerous snails during the winter. Water, pH 7.2 to 7.55.

Aquarium D.—Similar to B, but equipped with aerator and without glass top. Ocean sand, sea water and small marine life obtained from beach sand were placed in this aquarium in November 1937. Red and brown algae and sea lettuce were also put in; much of the latter had to be removed to obtain a proper balance. The water level was maintained by adding fresh water (1 pint) daily during winter months. Though a great diversity of species was originally placed in this aquarium, most of them were eliminated. The sea lettuce, red and brown algae, two small crabs, numerous protozoa, copepods and three species of nematodes survived. The latter seem to be doing well, males, egg-laying females and larvae being found. The species are *Metaparoncholaimus heterocytous* n. sp., *Oncholaimium oxyuris* v. *domesticus* n. var., and *Chromadora quadrilinea*. All three forms are apparently phytophagous and oxygen-loving. Algae grew on the aerator, sand became embedded therein and this spot is a veritable nest of oncholaims. Other specimens were found in the bottom sand and on the red alga, but not nearly in the abundance seen on the aerator. It is particularly interesting to note that we have, nematologically speaking, a culture of oncholaims and chromadorids despite the addition, from time to time of varied samples of other nematodes. Water, pH 8.2; total salt 3.35 per cent.

Tylenchus filiformis v. **abulbobus** n. var. Fig. 1A–B

Description.—Stylet devoid of any indication of knobs, prorhabdions, as seen in molting specimen, extremely short; excretory system on right side. Sublateral alae close together; striae exceedingly fine.

Male 630μ long; α, 38; β, 6.5; γ, 5.5. Spicules arcuate, distinctly subdivisible into capitulum calomus and lamina; gubernaculum present.

Female 609 to 709μ long; α, 24 to 27; β, 4.9 to 6.3; γ, 6 to 6.3; vulva 62 to 65%.

Habitat.—Debris at bottom of aquarium; original source, stream.

Locality.—Babylon, N. Y.

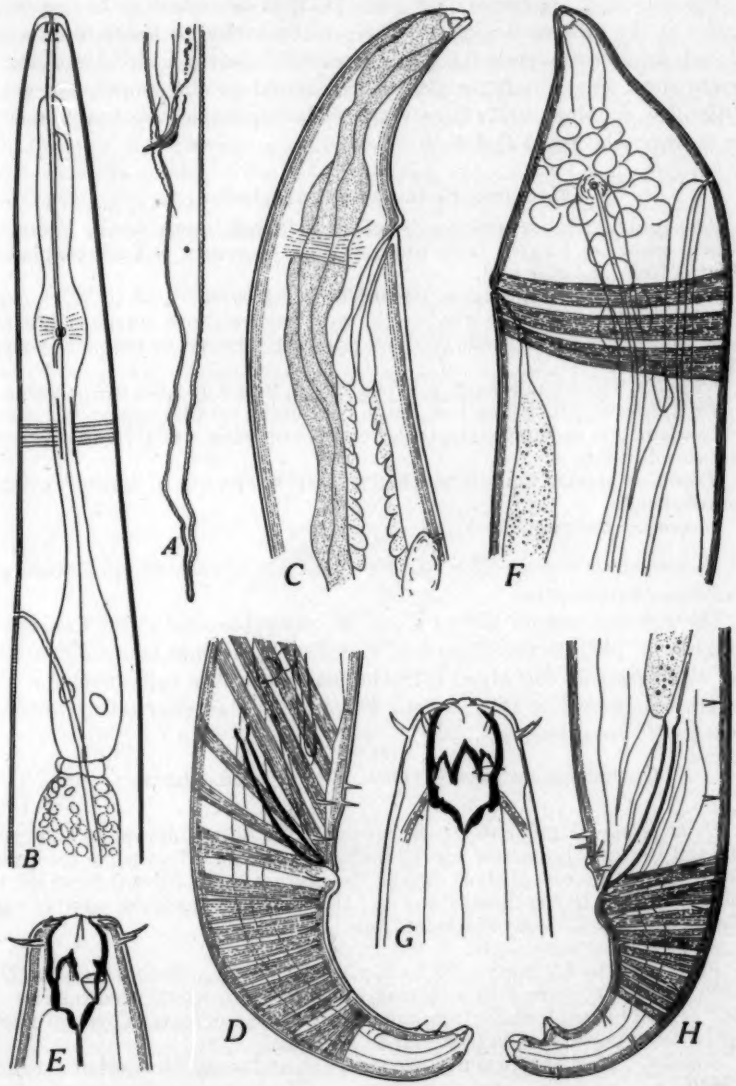


Fig. 1. A–B.—*Tylenchus filiformis* v. *abulbosus* n. var. (A, male tail; B, esophageal region). C–E.—*Metaparoncholaimus heterocytous* n. sp. (C, female tail; D, male tail; E. cephalic region). F–H—*Oncholaimium oxyuris* v. *domesticus* n. var. (F, female tail; G, head; H, male tail).

The species *T. filiformis* (Bütschli, 1873) is described as having weak knobs at the base of the stylet. The present variety is absolutely devoid of such knobs even when the gut is removed from the body. According to recent keys this variety would be transferred to the monotypic genus *Psilenchus* de Man, 1921. However, this hardly seems warranted, nor do we consider the genus *Psilenchus* as valid.

Metaparoncholaimus heterocytous n. sp. Fig. 1C–E

Description.—Subventral teeth subequal, dorsal tooth small. Excretory pore 4 stomatal lengths from anterior end; excretory cell 2.2 esophageal lengths from anterior end.

Male 3.7 to 4.3 mm long; α, 90 to 107, β, 8.6 to 10; γ, 38 to 50. Spicules 1 to 1½ anal body diameters in length, sometimes without apparent cephalation, sometimes cephalated. Without apparent preanal or postanal supplements.

Female 3.7 to 4.9 mm long; α, 65 to 100; β, 9 to 9.5; γ, 55 to 73; vulva 71 to 75%; uterus ¼ to ⅛ length of body, containing up to 6 eggs; tail 1.8 anal body diameters in length. Demanian system opening 2 anal body diameters anterior to anus.

Habitat.—Marine aquarium, among algae in vicinity of aerator; original source, beach.

Locality.—Babylon, N. Y.

Miscellaneous notes.—The intestine contains olivaceous sphaeroids and numerous heterocytes.

The present species differs from *M. campylocercoides* (de Coninck & Stekhoven, 1933) in the absence of a preanal appendage and it differs from *M. campylocercus* (de Man, 1878) in that the tail is cylindrical for ½ its length (compare Fig. 1C), and the vulva is more anterior (at 57 to 60 per cent in *M. campylocercus*).

Oncholaimium oxyuris (Ditl., 1911) v. **domesticus,** n. var. Fig. 1F–H

Description.—Similar to *O. oxyuris* but differing as follows: In *O. oxyuris* the tail is abruptly narrow and cylindroid in its distal half while the female is figured with a row of short eggs in the uterus; in the present form the tail is narrow only in the distal third and the female seems habitually to carry 2 eggs that are 1.5 body diameters long.

Male 4.3 mm long; α, 82; β, 9.3; γ, 50.

Female 3.5 to 4.2 mm; α, 53 to 85; β, 7.0 to 8.5; γ, 53 to 67; vulva 62 to 65%. Excretory pore 3 to 4 stomatal lengths from anterior end; excretory cell 1¾ esophageal lengths from anterior end. The demanian system apparently has 2 pairs of exits posterior to the anus.

Habitat.—Marine aquarium, among algae and on aerator; original source, beach.

Locality.—Babylon, N. Y.

Miscellaneous notes.—The intestine of this form contains neutral fats and olivaceous sphaeroids. The latter turn blue in nile blue sulphate, blue in potassium ferricyanide. After alcohol the latter cannot be stained, but

numerous small sphaeroids in the chords stain selectively. Birefringents are apparently confined to intestinal contents. The intestinal circumference includes 25 to 40 cells, the cells being rhomboidal to longitudinally diamond-form. Heterocytes are few; they contain small colorless sphaeroids and deep orange sphaeroids, the latter being similar in color to the intestinal contents. The faeces of this species contain some living bacteria and rich orange pigment which is quickly diffused in the water. The dead colorless bodies of many flagellates were seen in the faeces while similar, pigmented flagellates lived free in the aquarium. The demanian exit ducts may become colored by this pigment.

Chromadora quadrilinea Filipjev, 1918 Fig, 2A–B

Description.—Alae absent, cuticle punctate with 4 to 6 lateral rows of enlarged punctations. Amphids transversely elongated; 4 long cephalic setae. Stoma with 3 well developed, medially directed teeth. Esophagus terminated by a simple bulb. Intestine 4 to 6 or 8 cells in circumference.

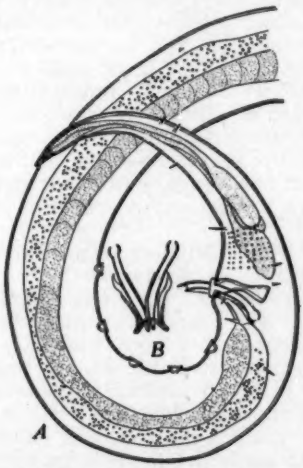


Fig. 2.—*Chromadora quadrilinea* Filipjev, 1918 (A, male tail; B, spicules and gubernaculum).

Male 816 to 840μ long; α, 28 to 35; β, 5.7 to 7.5; γ, 8.8 to 9. Spicules arcuate, indistinctly divisible into capitulum, calomus and lamina; lamina with delicate ala and distally forked. Gubernaculum with weak corpus and well developed crura with square ends. Supplementary organs 5 in number. Filipjev's (1918) original illustration shows no split in the spicule tip but this might be easily overlooked due to the complicated gubernaculum. He also characterized the species as having 6 supplementary organs but Micoletzky (1924) found specimens from the Mediterranean with 5 supplements.

Female 730 to 840μ; α, 22 to 25; β, 6.3; γ, 7.4 to 8; vulva, 47 to 52%.

Habitat.—Marine aquarium, in sea lettuce (*Ulva*) and on aerator.

Locality.—Babylon, N. Y.

Miscellaneous notes.—The intestine contains bright orange sphaeroids soluble in alcohol, birefringent, with negative ninhydrin reaction. Apparently they represent absorbed chlorophyl. The large cell posterior to the excretory cell is apparently a coelomocyte which functions as an athrocyte extracting neutral red or methylene blue from solution; 4 or 5 heterocytes in the posterior third of the intestine behave similarly.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

CHEMICAL SOCIETY

501ST MEETING

The 501st meeting was held at the University of Maryland, College Park, Maryland, on Thursday, May 12, 1938, President DRAKE presiding. The meeting was preceded by an informal dinner in the University Dining Hall. After the reading of the minutes the Secretary gave a brief report on the Dallas meeting of the American Chemical Society. Of especial interest to the Society was the adoption by the council of resolutions submitted by the Chemical Society of Washington, and dealing with the indiscriminate sale to the public of possibly dangerous drugs, such as the recently notorious "elixir of sulfanilamide," which caused upwards of seventy deaths. The resolutions as adopted read as follows: "*Resolved*, that the American Chemical Society, the representative body of American chemists, urges the Congress of the United States to set up reasonable and adequate safeguards for the public in all cases of new drugs, substances and mixtures thereof, for use in the diagnosis, cure, mitigation, treatment or prevention of disease in man or other animals."

After the conclusion of the business session, the Society divided into three sections for the reading of papers.

Section of inorganic chemistry, C. E. WHITE presiding.

JOHN KEENAN TAYLOR and EDGAR REYNOLDS SMITH: *Reproducibility of the silver-silver chloride electrode.*—A study was made of the reproducibility of the electrolytic, thermal-electrolytic, and thermal types of the silver-silver chloride electrode in 0.05 *N* solution of potassium chloride. The presence or absence of light, and of air dissolved in the solution, have no significant effect on their potentials. A marked aging effect was noted, the origin of which was traced to concentration-polarization occurring during the preparation of the electrodes. The attainment of concentration equilibrium between freshly-prepared electrodes and solution is slow and may require from 1 to 20 days, depending on porosity of the electrodes and stirring of the solution. For the same reason, freshly-prepared electrodes behave as cathodes towards aged electrodes, the initial difference in potential often exceeding a millivolt. When sufficient time is allowed for the establishment of concentration equilibrium, these types of silver-silver chloride electrodes assume the same potential, within about 0.02 mv. The significant effect of concentration-polarization and the requirement of sufficient aging time to attain concentration equilibrium within the porous silver chloride, offer a possible explanation for the conflicting data in the literature on this electrode. (*Authors' Abstract.*)

A. L. PITMAN: *Electrochemical production of sodium chlorate.*—This paper has been published in Chem. and Met. Eng. **44**, 302 (1937).

F. C. KRACEK, G. W. MOREY, H. E. MERWIN: *The system: water-boron oxide.*—The equilibrium diagram for the system of water and boron oxide has been established by measuring the solubility over the whole range of compositions. The crystalline phases which occur in the system are: ice, H_3BO_3, three modifications of HBO_2, which are monotropically related to each other, and crystalline B_2O_3. Solubility relations have been determined for each of these phases.

The solubility curve for ice extends only from the melting point of ice to the cryohydric point at -0.76°C. The curve for H_3BO_3 rises smoothly from this point to a maximum at the melting point (metastable) of H_3BO_3, 170.9°C, and then descends, to end at the metastable eutectic for HBO_2III and H_3BO_3. The three forms of HBO_2 melt congruently; HBO_2I, the stable modification, at 236°C, and HBO_2II and HBO_2III, both metastable, at 200.9°C and 176.0°C, respectively. Their solubility curves have flat maxima at the composition HBO_2. The curve for the stable form, HBO_2I, intersects the curve for H_3BO_3 at 169°C, at which point H_3BO_3 decomposes to form HBO_2I and a solution of the equilibrium composition. The reaction is abnormally sluggish, so that the metastable continuation of the solubility curve of H_3BO_3 is realized as if HBO_2I did not exist. The curves of HBO_2II and HBO_2III intersect that of H_3BO_3 at metastable eutectics located at 169.6°C and 158.5°C respectively. Crystalline B_2O_3 melts at $450° \pm 2$°C. It has been crystallized from solutions in sealed tubes, as well as in open vessels at atmospheric pressure, and various factors influencing its spontaneous growth have been established. The solubility curve extends from the melting point to the intersection with the curve of HBO_2I at 235°C, and with that of HBO_2II at 200°C. Both of these points are eutectics, the second being metastable. From the slope of the solubility curve the latent heat of fusion of B_2O_3 is calculated to be 97 cal/g.

P-T-X relations for the saturated solutions have been evaluated by combining the solubility data with deductions based on existing vapor pressure measurements. The resulting diagram brings out among other things the interesting fact that, contrary to prevalent suppositions, B_2O_3 can coexist in the crystalline form with solutions at a considerable vapor pressure of water vapor, this being nearly 3 atmospheres in the neighborhood of 280°C. The oxide crystallizes relatively rapidly in sealed tubes at this temperature. On the other hand, it crystallizes exceedingly slowly from nearly anhydrous melts of vitreous B_2O_3, and never spontaneously, in this region of composition. The spontaneous crystallization is initiated in the more highly aqueous solutions by the presence of HBO_2I, but not by the presence of the other modifications of metaboric acid.

The crystallographic and optical properties of the new crystal phases were measured, and are described in detail in the complete text. (*Authors' Abstract.*)

Section of physical chemistry, M. M. HARING presiding:

F. G. BRICKWEDDE: *The vapor pressure differences of isotopic modifications of methane.*—Working with Mr. R. B. Scott, of the Cryogenic Laboratory of the National Bureau of Standards, measurements were made of the differences between the vapor pressures of CH_4, two samples of CD_4 prepared in different laboratories, and single samples of CD_3H, CD_2H_2 and CDH_3. The non-methane impurities of the methane samples were removed by fractional distillation and their isotopic compositions were determined in one laboratory using a mass spectrometer and checked in another laboratory using a different mass spectrometer. Using the analyses and the vapor pres-

sure data, the vapor pressures of the pure isotopic varieties were calculated.

At the boiling point of methane (−152°C) the vapor pressure of a heavy methane is greater than that of a lighter isotopic variety. The sign of the vapor pressure difference for the liquid methanes is opposite to that for H_2, HD and D_2 for which the heavier variety has the lower vapor pressure. However, the sign of the vapor pressure differences of the methanes changes at lower temperatures so that at temperatures below −200°C the vapor pressure of a heavy solid methane is lower than that of a lighter variety.

The normal behavior has been considered to be that which gives rise to a lower vapor pressure for the heavier variety as in the case of H_2, HD and D_2, and the solid methanes below −200°C. Heavy acetic acid (CH_3COOD) and deuterium fluoride have higher vapor pressures than their corresponding light varieties, the greater vapor pressure of the heavier variety being attributed to molecular association in the vapor state. This explanation is not applicable to the methanes. It is proposed that the greater vapor pressure of a heavier isotopic variety arises from a decrease, upon condensation of a vapor, in the frequency of some internal motion of a molecule or of an associated molecule. Such frequency changes upon condensation have been observed experimentally in the Raman and infra-red absorption spectra of vapor and condensed phases.

A general law is proposed for vapor pressure differences of isotopic molecules: "Vapor pressure differences of isotopic varieties arise because of quantum effects, and disappear for conditions under which classical and quantum theories give equivalent results. Vapor pressure differences are connected with a change in the frequency of some intermolecular or intramolecular motion in the process of vaporization. A decrease in some frequency (e.g., frequency of intermolecular vibrations of a lattice) acts in the direction to make the vapor pressure of the heavier variety less than that of the lighter, whereas an increase in some frequency (e.g., the frequencies of intramolecular vibrations of methane, or acetic acid and hydrogen fluoride dimmers) acts in the direction to make the vapor pressure of the heavier variety greater." (*Author's Abstract.*)

JOHN BEEK, JR.: *The calculation of entropy from measurements of heat capacity.*—The usual method of obtaining the entropy of a substance as a function of the temperature is to evaluate the integral

$$S_2 - S_1 = \int_{T_1}^{T_2} \frac{C}{T} dT. \tag{1}$$

The principal source of error in this method is in the calculation of the heat capacity from differences between measured values of the temperature. This source of error may be eliminated from the calculation by considering the measurements as giving the heat content, rather than the heat capacity, as a function of the temperature. The entropy is then calculated according to either of the following equations, which are equivalent as regards precision.

$$S_2 - S_1 = \int_{T-T_1}^{T-T_2} \frac{1}{T} d(H - H_0) \tag{2}$$

$$S_2 - S_1 = \frac{H_2 - H_0}{T_2} - \frac{H_1 - H_0}{T_1} + \int_{T_1}^{T_2} \frac{H - H_0}{T^2} dT. \tag{3}$$

If an adiabatic calorimeter is used in making the measurements, the heat content is given directly as a function of the temperature. If a non-adiabatic calorimeter is used, the change in the heat content of the sample corresponding to the drift of the temperature between successive measurements may be calculated from an interpolated value of the heat capacity.

A series of measurements made by Bekkedahl and Wood, J. Research Natl. Bur. Standards **19**: 551. 1937, during their investigation of the thermodynamic properties of isoprene is used to illustrate the improvement in precision obtained by the method of this paper. It is found that the uncertainty in the value of ΔS for the interval from 200° to 300°K is in this case of the order of ten times as great when the heat capacity is used as it is when the heat content is used for the calculation. (*Author's Abstract.*)

PAUL S. ROLLER: *Size distribution and statistical size constants of subdivided materials.*—Typical analyses (percentage by weight at different sizes) are given for various materials, including ball clay, kaolin, talc, hydrated lime, soil, litharge, cement, flint, pulverized coal and run-of-mine coal. To assess the size character of these materials statistically, it is necessary to have a distribution function. Such a function is provided by the equation: $y = ax^{1/2}e^{-b/x}$, where y is percentage by weight of all sizes less than x, and a and b are parameters. Significant statistical size constants are, surface area per gram, number of particles per gram, coefficient of uniformity, and efficiency ratio (efficiency of mechanical reduction of the coarsest sizes). All of these are simple functions of the distribution parameters a and b. For example, surface area is proportional to $(a/b)^{1/2}$, and coefficient of uniformity to $ab^{1/2}$, the proportionality constant including a factor, usually close to unity, which takes into account the finite upper limit of size.

For the materials cited above, surface area ranges from 200,000 to 400,000 sq.cm/gm for ball clay, through 20,000 to 75,000 for kaolin, 12,000 for talc, 4000 to 6000 for hydrated lime, 4000 for certain soils, 2000 for cement and 12 for run-of-mine coal. The coefficient of uniformity at about 0.1 is lowest for the run-of-mine coal and for talc, indicating a tendency to produce an excess of fines. On the other hand, the coefficient at about 1.15 is unusually high for litharge (sublimed) and for hydrated lime (chemical crystallization). It will be noted that these materials are produced by crystal growth rather than by mechanical reduction; the relatively small production of fine sizes is thereby understandable.

For coarse material, such as run-of-mine coal, crushed ores, etc., a double distribution occurs, each distribution however satisfying the same law given above. The origin of the double distribution is believed to be the presence of points of weakness (edges, corners and crystal defects) which give rise on shear to a secondary aggregation of fine sizes. As the material becomes finer, the parameters of the two distributions become more nearly alike until the distributions appear to merge into the one distribution that is characteristic of finely divided material. (*Author's Abstract.*)

Section of organic chemistry, N. L. DRAKE presiding:

C. S. HUDSON: *The structure of sedoheptulosan (anhydro-sedoheptose).*—This paper has been published in J. Am. Chem. Soc. **60**: 1241. 1938.

S. PALKIN, E. E. FLECK and T. C. CHADWICK: *Cyclic mono- and di-terpene derivatives of pine oleoresin.*—Two distinct types of pine oleoresin (from same species of trees, P-palustris and P-caribaea), one from old stumps, the other from the living tree, were described and differences in composition pointed out. The turpentine portion of stump resin oil was shown to consist mainly of dicyclic monoterpene—α-pinene; several monocyclic hydrocarbons; small

amounts of secondary and tertiary alcohols, oxides, phenols, phenol ethers and other compounds: that from the resin of the living tree consisted essentially of the two dicylic terpene isomers, α- and β-pinene.

The diterpenes, a complex series of isomeric resin acids, were discussed as to properties and methods of isolating individual isomers. Derivation of structure and distribution of the two double bonds in the three isomers, α- and β-pimaric acids and l-abietic acid, was briefly reviewed. The highly stable so-called "pyroabietic" acids (formerly considered isomers) were discussed as to method of preparation and experiments leading to resolution of the complexes by fractional crystallization of ammonium salts and methyl esters into dehydro-, dihydro- and tetrahydro-abietic acids. Isolation of dehydro- and hydrogenated acids, together with gasimetric data obtained from closed system experiments, showed the reaction involved in conversion of abietic acid to "pyroabietic" acid was essentially one of dehydrogenation and disproportionation. (*Authors' Abstract.*)

B. A. BRICE, E. E. FLECK and S. PALKIN: *Ultra-violet absorption spectra as an aid in studying isomeric resin acids.*—Preliminary results in an investigation of the ultra-violet absorption spectra of pine resin acids were presented. Levo-abietic acid showed four poorly resolved absorption maxima with principal maximum at 242 mu. Oxidation was shown to decrease the intensity of absorption in this region. Levo-pimaric acid showed three poorly resolved maxima, with peak absorption at 271.5 mu. Dextro-pimaric acid gave similar but weak absorption in this same region, and it was concluded that the sample examined contained a small proportion of l-pimaric acid. Samples of α-pyroabietic acid, its methyl ester, and dehydroabietic acid showed three maxima, the long wave-length maximum at 276 mu being particularly well-resolved. Additional maxima at 251 and 242 mu for the latter sample were interpreted as being due to about 1% of levo-abietic acid as an impurity. It was concluded that the principal constituent of α-pyroabietic acid and dehydroabietic acid are at least similar in structure. Weak absorption maxima obtained for a sample of tetrahydroabietic acid were attributed to the presence of a small amount of dehydroabietic acid. Samples of dihydro-l-pimaric and dihydro-d-pimaric acids showed no trace of absorption maxima for less saturated acids. (*Authors' Abstract.*)

FRANK C. KRACEK, *Secretary.*